# IV. *On the Structure and Relations of the Alcyonarian* Heliopora cærulea, *with some Account of the Anatomy of a Species of* Sarcophyton, *Notes on the Structure of Species of the Genera* Millepora, Pocillopora, *and* Stylaster, *and Remarks on the Affinities of certain Palæozoic Corals. By* H. N. Moseley, *M.A. Oxon., Naturalist to the 'Challenger' Expedition. Communicated by Professor* Wyville Thomson, *F.R.S., Director of the Civilian Staff of the 'Challenger.'*

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## *Introduction.*

Having undertaken the examination of the Deep-sea Corals dredged by the 'Challenger' during her voyage, my attention was naturally directed to the study of the structure of corals generally. The Milleporidæ, both because of their peculiar tabulate structure and relations to fossil forms, and because of Prof. Agassiz's well-known determination of them as Hydroids and not Actinozoa, seemed to offer the most interesting field for investigation; and I accordingly commenced the examination of their structure very early in the cruise of H.M.S. 'Challenger' in April 1873, at Bermuda, where *Millepora alcicornis* occurs in great profusion.

I made a number of preparations and made out some points in the anatomy of this species, but found the subject to be so difficult that I put the matter aside to be further examined on reaching England. In the beginning of 1875, however, I obtained specimens of *Heliopora cærulea* in the living state at Zamboangan, and on examining these found to my astonishment that *Heliopora* was an Alcyonarian. I therefore during subsequent voyages made as complete an examination as possible of this species, and examined for comparison with it the structure of another Alcyonarian, a species of *Sarcophyton* dredged in shallow water amongst the reefs of the Admiralty Islands. I examined further the structure of a species of *Millepora* obtained at Zamboangan; and I also examined a *Pocillopora* found at the same locality, and a species of *Stylaster* dredged in 500 fathoms off the Meangis Islands. The results form the substance of the present paper.

## *Recent Literature concerning Tabulate and Rugose Corals and Alcyonarians &c.*

I am able to refer to very few original papers relating to the present subject, but have gathered the following from the more general works available on board the 'Challenger.' It is hoped that allowance will be made for the peculiar conditions under which this paper is written.

M. Milne-Edwards (Hist. Nat. des Coralliaires, Paris, 1860, t. iii. p. 224) forms the

family Milleporidæ to include a series of genera, amongst which *Millepora* and *Heliopora* are the only recent ones, whilst he classes the Pocilloporinæ as a subfamily of the Favositidæ, together with the Milleporidæ and Seriatoporidæ, under his section of the Madreporaria Tabulata. The section is characterized by having the corallum composed essentially of a much developed mural system, with the visceral chambers divided into a series of stories by complete diaphragms or transverse floors, the septal arrangements being rudimentary or represented by trabeculæ, which have a greater or less extension in the intertabulate spaces. In his description of the Milleporidæ (*l. c.*) M. M.-EDWARDS refers to Prof. AGASSIZ's then recent paper, entitled "Les Animaux des Millépores sont des Acalèphes Hydroides et non des Polypes," Bibl. Univ. de Genève, Arch. des Sci., Mai 1859, t. v. p. 80, to the following effect:—"At the moment of sending this chapter (on the Madreporaria Tabulata) to the press, we learn that Prof. AGASSIZ has studied the mode of the organization of the soft parts of the Milleporidæ, and has proved that these Zoophytes are not corals, but Hydroid Acalephs very nearly related to the Hydractiniæ. Prof. DANA shares the opinion of Prof. AGASSIZ; and AGASSIZ believes that the Favositidæ, as well as all other species of which the septa are not continued vertically, ought to be considered strangers to the class of corals. But the facts on which he grounds his opinion are not as yet sufficiently ascertained for us to be able to form a critical opinion of their value; and until more ample information is received, we shall continue to rank the polyps in question according to the method adopted in our former works."

Professor L. AGASSIZ, in his 'Contributions to the Natural History of the United States,' vol. iii. plate 15, figured the animals of *Millepora*. He places *Millepora*, *Heliopora*, *Seriatopora*, *Pocillopora*, the whole of the Tabulate and Rugose Corals, with the Hydroid Acalephæ. The principal distinction between these sections and true polyps relied on by AGASSIZ, as quoted in BRONN'S 'Klassen und Ordnungen des Thierreichs' (Actinozoa, 1860, p. 45, note), is as follows:—"True polyps should have unbroken septa throughout the whole calicle, with only separated horizontal partitions between them. On the other hand, the hydroid Favositidæ had complete horizontal partitions between interrupted septa." Professor AGASSIZ hoped that deep-sea dredgings would produce additional evidence concerning the affinities of *Millepora*, and genera connecting more closely the Rugosa and Tabulata with one another and with the Acalephæ in the shape of branching Heliopores and the like. (A letter concerning Deep-sea Dredgings, addressed to Prof. BENJAMIN PIERCE, Superintendent of the United States Coast Survey, by LOUIS AGASSIZ. Cambridge, Mass., Dec. 1871). Since AGASSIZ's observations on *Millepora* were published, no one has made any examination of the structure of the soft parts of any of the members of the Tabulata, with the exception of Prof. VERRILL, who has examined a *Pocillopora* and found it to be a true Zoantharian polyp with twelve septa and twelve tentacles (Ann. & Mag. Nat. Hist. 1872, vol. ix. 4th series, p. 355, from SILLIMAN'S 'American Journal,' 1872, vol. iii. pp. 187–194, "On the Affinities of Palæozoic Tabulate Corals with Existing Species").

Professor VERRILL, in the paper above quoted, as he has done before, combats the conclusions of Prof. AGASSIZ, that the whole of the Tabulata belonged to the hydroid polyps. This fact, he says, has only been proved for the Millepores: the remaining Tabulata should be joined with the true polyps, with which their relations are very near and intimate. The transverse partition-walls, the presence of which was held by MILNE-EDWARDS and HAIME as a characteristic distinction, are structures of a very low order, that occur *in widely different forms*, and are only brought about by the simultaneous emptying of the generative products from the radial chambers. Where the emptying is not thus periodically simultaneous, a separate transverse septum is formed in each of the chambers shutting off the space thus become vacant. True tabulæ are found not only in *Millepora* and *Pocillopora*, but in *Cœlastræa*, *Alveopora*, and *Asteropsammia*. *Columnaria* is, apparently, closely allied to *Cœlastræa*, *Favosites* to *Alveopora*, *Porites*, &c. *Heliopora* being shown to be an Alcyonarian, tabulæ are proved to be present in forms still more widely different than is shown to be the case by Prof. VERRILL. The relation of *Favosites* and *Columnaria* appears now in a different light.

The opinions expressed concerning Professor AGASSIZ's relegation of the Tabulate and Rugose Corals to the Hydroids have been various.

Professor ALLMAN, in his 'Monograph of the Gymnoblastic or Tubularian Hydroids' (London, published for the Ray Society by ROBERT HARDWICKE, 192 Piccadilly, 1871, page 3), refers to Professor AGASSIZ's opinion on the subject as published in his 'Contributions to the Natural History of the United States.' He considers that since we are entirely ignorant of the generative system of the Milleporidæ, it is much safer to wait for such verification as may be expected from further researches. He hesitates to include amongst the Hydrozoal orders the Tabulate and Rugose corals. Professor ALLMAN (Quart. Journal Micr. Science, vol. lxii. pp. 394, 395) considers *Edwardsia* to occupy an intermediate position between Zoantharian and Alcyonarian polyps, and to be comparable with the extinct Rugosa, to which it corresponds in the numerical law of its body-segments.

Count POURTALÈS (Illustrated Catalogue of the Museum of Comparative Anatomy at Harvard College, Cambridge, Mass.: No. iv. Deep-sea Corals, p. 56) places the Milleporidæ with the Hydroids. He remarks, "No observations have been made on *Millepora* since Professor AGASSIZ's first announcement of the affinities of the Millepores with the Hydroid polyps twenty years ago. The polyps of *Millepora* are very difficult to observe, both because of their small size, and because they are killed by the shortest contact with air; when obtained expanded, they contract on the slightest shake of the vessel containing them. I have succeeded but once in having a good view of one of the larger polyps of *Millepora alcicornis* in company with Professor AGASSIZ. It differed from the figure in the 'Contributions to the Natural History of the United States,' vol. iii. plate 15. fig. 1, in being comparatively shorter and having larger tentacles, or rather *tentacular masses* studded with lasso cells five in number instead of

four. The mouth was not seen very distinctly, but appeared to be a transverse slit in the middle of the disk. It remained expanded but a short time."

POURTALÈS places the genus *Pliobothrus* amongst the Milleporidæ. The Rugosa he places at the end of the true corals. He has by the examination of the *Lophophyllum proliferum* (M.-EDWARDS and HAIME) come to the conclusion that the tetrameral arrangement claimed for the Rugosa is only apparent, there being originally six primary septa. The coral was examined by cutting successive transverse sections. Such a section from the tip of *Lophophyllum proliferum*, representing the youngest stage, shows six primary septa and six interseptal spaces placed symmetrically on two sides of a vertical plane and unequally developed. By unequal development of additional septa in further development (investigated by the examination of sections successively nearer to the margin of the calicle) the seeming tetrameral arrangement is produced. POURTALÈS refers to papers on the subject by RÖMER and LINDSTRÖM, and cites L. LUDWIG (H. von MEYER'S 'Palæontographica,' vols. x. & xiv.) as having shown the same facts and come to like conclusions concerning the affinities of the Rugosa, publishing his results before POURTALÈS.

A. KUNTH (Zeitschrift der deutsch. geol. Ges. xxi. Heft 3) is also cited by POURTALÈS. KUNTH has examined the law of growth of the Rugosa chiefly by the consideration of the successive development of the costæ. He still adheres to the tetrameral primary division, from want, in the opinion of POURTALÈS, of having examined individuals of very young age and hence great simplicity.

KUNTH is further quoted in LEUCKART'S Jahresbericht, 1870–71, p. 192, as finding the analogue of the operculum of Zoantharia Rugosa in the folds of skin described by MILNE-EDWARDS as occurring in *Cryptohelia pudica* " trotz der fehlenden Verkalkung." There must be some error here. Surely KUNTH refers to the calcareous lamina projecting in front of the mouth of the calicle of *Cryptohelia* springing from its margin.

KUNTH (Zeitschrift der deutschen zoolog. Gesellschaft, 1870, p. 81; LINDSTRÖM, Œfvers. Kongl. Vetensk.-Akad. Förhandl. Bd. xxvii. pp. 922–926), the first discoverer of the opercular apparatus of Rugosa, compares the opercula to the skeletal structures of certain Primnoas, especially *Primnoa lepadifera*, *Paramurina placomus*, and *Cyathophyllum Loveni*. *Goniophyllum pyramidale* had four valves at the anterior end placed in pairs opposite one another, and only differing in that one of them is larger than the others. This larger one is the homologue of the one opercular valve of *Calceola* and *Rhizophyllum*.

Prof. CLAUS (Grundzüge der Zoologie, 3te Auflage, 1874, p. 226) places the Milleporidæ with the Hydroids. The Rugosa he considers should be separated as a third order of Anthozoa equivalent to the Alcyonaria and Zoantharia, and remarks on the relations between Rugosa and Hexactinia shown by the developmental history of the latter.

SAVILLE KENT (Ann. & Mag. Nat. Hist. 1870, vol. vi. pp. 384–387) describes *Favositi-*

*pora Deshayesii* as an existing coral closely allied to the palæozoic genus *Favosites*. The coral has abundant complete horizontal partitions and closely resembles *Alveopora fenestrata*; it connects the Favositidæ and Poritidæ, and is a new proof that the Tabulates belong to the Anthozoa and not to the Hydroids.

Prof. P. MARTIN DUNCAN ("A Description of the Madreporaria dredged up during the Expeditions of H.M.S. 'Porcupine' in 1869 and 1870," Trans. Zool. Soc. London, vol. viii. part 5, p. 335) describes *Guynia annulata* as a recent Rugose coral. In this coral there is no endotheca. In three specimens there were evidences of a hexameral septal arrangement. One had an octameral arrangement at the base and a hexameral at the calicular margin. This specimen is believed to illustrate the formation of the Neozoic type from the Rugosa. Prof. DUNCAN has treated on the affinities of *Guynia* with *Haplophyllia* in a paper in Phil. Trans. Roy. Soc. 1872, which paper I have not seen. *Haplophyllia paradoxa* is another recent supposed representative of the Rugosa from the deep sea described by POURTALÈS in the 'Bulletin of the Museum of Comparative Zoology, Harvard Coll. Camb. Mass.' no. 7, and also in his work on deep-sea corals already cited. Unfortunately the soft parts of neither *Guynia* nor *Haplophyllia* were obtained for examination.

The latest paper treating on the classification of corals to which I have access is by M. G. DOLLFUS (" Observations critiques sur la classification des Polypiers paléozoïques," Comptes Rendus de l'Acad. des Sciences, t. lxxx. no. 10, 15 Mars 1875, pp. 681–683). M. DOLLFUS classes certain of the Tabulata, the Héliolitiens (*Heliolites*, *Lyellia*, *Propora*), with the modern Milléporiens (*Heliopora*, *Millepora*, *Seriatopora*), connecting them by the Pocilloporiens (*Pocillopora*, *Axopora*, *Polytremacis*) most unfortunately, since *Pocillopora* is a Hexactinian. He considers all these genera to be Hydroids. The Chætétiniens (*Stellipora*, *Monticulipora*, *Chœtetes*, *Cœnites*, *Dania*, *Beaumontia*, *Labechia*, *Dekaya*) he considers to be Bryozoa allied to the Jurassic *Heteropora* and Cretaceous *Radipora*. The group of Favositiens (*Alveolites*, *Favosites*, &c.) presents, as he considers, relations with the tubuline Bryozoa, the Cyclostomata.

It will be seen from the above abstracts that the relations of the Tabulate and Rugose Corals are in a very uncertain condition, and that there is very wide difference of opinion on most important points. It is hoped that some light will be thrown on the subject by the present paper.

In addition to the authors cited above, the following papers and works will be referred to in the sequel (they have mostly been accessible only in abstract) :—


QUENSTEDT . . . . Handbuch der Petrefactenkunde. Tübingen, 1867.

METSCHNIKOFF . . . On the Development of *Kalliphobe* (BUSCH). Bullet. Acad. Impér. St. Pétersbourg, t. xv. pp. 502, 503.

LACAZE-DUTHIERS . . Hist. de Développement des Coralliaires. Arch. Z. expér. i. pp. 289–296.

SARS . . . . . . . On the Polyps of *Allopora oculina*. Forh. Selsk. Chr. 1872, p. 115.

Prof. A. SCHNEIDER and M. RÖTTEKEN. On the Structure of Actiniæ and Corals. Sitzungsbericht der oberhessischen Gesellschaft für Natur- und Heilkunde. 1 March, 1871.

KÖLLIKER . . . . Anatomisch-systematische Beschreibung der Alcyonarien. Abh. der sensk. naturf. Gesell. Frankfurt, 1870. To this work I was able to make a short reference at Yeddo through the kindness of Dr. HILGENDORF.

KÖLLIKER . . . . On the frequent occurrence of Vegetable Parasites in the hard tissues of Animals. Quart. Journal of Microscopical Science, 1860, vol. viii. p. 171.

Dr. CARPENTER . . . On the Structure of the Shells of Molluscous and Conchiferous Animals. Trans. Microscopical Society, 1844, ser. 1, vol. i. p. 123.

*Methods.*—The corals and the *Sarcophyton* examined were hardened in absolute alcohol, being placed in it in the living condition. Portions of them were subsequently decalcified in weak hydrochloric acid, imbedded in wax in the usual manner, and sections were then prepared from them. The sections were examined partly in glycerine, partly in Canada balsam, after being rendered transparent by means of oil of cloves. Some sections were stained with carmine. Some portions of *Heliopora* were placed whilst living in a solution of chromic acid, and slowly decalcified whilst in the solution by the addition of a few drops of hydrochloric acid from time to time; these yielded some results which were not obtainable from specimens hardened in alcohol and more rapidly decalcified. Further sections of small area were forcibly cut from the undecalcified hardened corals in order to show the relations of the hard parts to the soft, and separate polyps were removed from their calicles with the point of a scalpel and examined whole in glycerine. Portions of the tissues of *Heliopora* were also observed in the fresh condition.

For examination of the structure of the hard calcareous tissues, fine sections were prepared by grinding in the usual manner.

### *Account of the structure of* Heliopora cærulea.

*Heliopora cærulea* was found growing in abundance on the reefs fringing the shore of the small island of St. Cruz Major, which lies opposite the harbour of Zamboangan, Mindanao, Philippine Islands. The coral grew in about two feet of water at low tide. It has a uniform light chocolate-colour when fresh and living. Although I transferred portions of the living coral to a glass vessel under water so that they never came in contact with the air, I did not succeed in getting the polyps to expand; and I have

not seen them in that condition, although directly the coral was left at rest a swarm of a species of *Leucodora*, closely resembling *Leucodora nasuta*, which infests the coral and perforates it all over, expanded themselves at once. Most unfortunately I hardened in spirits portions of *Heliopora* taken from only one colony, as I did not suspect that the animal would prove to form unisexual colonies. This colony proved to be female; and hence I have not seen the male generative organs of *Heliopora*. The only reference to the structure of the soft parts of *Heliopora* which I have found is a statement of QUENSTEDT (*l. c.* p. 795), that QUOY says that the animals of *Heliopora* have more than twelve rays.

### *Structure of the Corallum of* Heliopora cærulea*.

The genus *Heliopora* was formed by BLAINVILLE (Manuel d'Actin. p. 392). It is thus characterized by MILNE-EDWARDS, *l. c.* p. 230:—"Corallum massive, lobulate, and rising in a tuft. Cœnenchym very abundant, and presenting at its surface a great number of rounded pores, disposed with regularity and separated by projecting papilliform grains. These grains are formed by the upper extremities of an equal number of cylindrical and vertical beams, which shut in tubuliform spaces, open above, and divided from space to space by cross partitions. Calicles circular. Septa very little developed, but distinct and 12 in number. Horizontal floors present and well developed. The genus is remarkable for its alveolar appearance and the tubular structure of the parenchym."

The coral is figured by M.-EDWARDS, *l. c.* pl. 1. figs. 3*a*, 3*b*, 3*c*. A drawing of the growing tip of a frond, much enlarged, will be found on Plate 9. figs. 16 and 17 of this paper. The following points require to be remarked concerning the structure of the corallum. The papilliform eminences described by M.-EDWARDS as covering the surface of the corallum spring from the points of apposition of the walls of several of the cœnenchymal tubes, very usually from the point of meeting of the mouths of four tubes (Plate 9. fig. 17); here the hard tissue consists of a thickened vertical beam of calcareous matter, from which thin lamellar-like processes are given off, which form the walls between two contiguous tubes by crossing to join similar processes from the thickened beams situate at the point of apposition of these two tubes with the pair next succeeding them in the same direction. The narrow summits of the thin laminæ forming the sides of the tubes fall short in their centres, by a considerable distance, of the level of the thickened masses from which they spring, but are rather excavated or hollowed out at these spots; and it is across these excavations in the laminæ that the deep system of canals passes in the fresh condition of the animals, by means of which the cavities of the tubes and polyps communicate freely with one another. The structure of the cœnenchym of the coral might be better described by saying that it consists of a series of tubes of circular

* I regret extremely that I am unable to refer to MM. MILNE-EDWARDS and HAIME's papers, "Recherches sur les Polypiers," Ann. Sc. Nat. iii., ix., xvi.

section of nearly uniform diameter, closely packed side by side more or less in regular rows, with their walls where touching fused together, and the spaces necessarily resulting from such an arrangement at the meeting-points of every three or four contiguous tubes filled in with calcareous matter, forming rods or beams of hard tissue, which are elevated above the margins of the tubes into papilliform prominences. MILNE-EDWARDS distinguishes between the tabulæ of the cœnenchymal tubes and those of the calicles, calling the first "traverses," the second "planchers horizontaux;" but these are essentially similar structures. Though twelve is a common number for the projecting plications of the margin of the mouth of the calicle, the number is very variable; 11, 13, 14, even 15 or 16 of these so-called septa are to be counted not uncommonly. In the enlarged figure of a calicle (fig. 17, Plate 9) Mr. WILDE has drawn fifteen. The plications become less numerous at a slight depth in the calicle, and often here are only eight in number, with a mesentery of the polyp passing to each internal projection.

The fine structure of the hard tissue of *Heliopora* is in many respects similar to that of the coralla of Hexactinian corals. It is composed of doubly refracting calcareous matter, which has half-crystalline, half-fibrous structure. On transverse section, fig. 4. Plate 8, it is seen to be made up of a series of systems of radiating fibres, *i. e.* areas of calcareous tissue showing a radiate fibrous structure. In each system the fibres radiate from a central axis and diverge to fuse at the margin of the system with the margins of the contiguous systems, a suture-like line being often observable where two systems join. The fibres are dispersed more or less in laminæ which overlap one another. The radial fibrous structure is to be seen only in thin slices or fragments of the coral viewed by transmitted light. The fracture of the coral is irregular and crystalline. The central axes of the systems correspond to the centres of the vertical beams already described, which are prolonged above on the surface of the coral into papilliform projections. In a vertical section of the corallum (fig. 11, D, Plate 9) these axes are seen to take a vertical course within the beams and branch beneath the newly formed buds of the cœnenchym. The fibres are seen starting from the axes, spreading right and left from them throughout the tissue, with a uniform inclination upwards (*i. e.* towards the surface of the corallum). In the plates forming the sides of the tubes (B, fig. 11, Plate 9) the sutures between the fibres meeting one another at an angle from the two systems are well marked. The appearance of a portion of the hard tissue, as seen under a high power, is shown in fig. 12, Plate 9, where the appearance of the overlapping laminæ is to be remarked. In the corallum of *Pocillopora* definite rod-like prisms with polygonal ends are to be seen to exist by viewing these structures end on; in *Heliopora* such a definite structure apparently does not occur*.

* The radiating components of the hard tissue are here spoken of as fibres to distinguish them from these well-marked prisms of which the hard tissue of *Pocillopora* is composed. The exact nature of the radial striæ seen in the tissue of the *Heliopora* I do not understand; they seem to represent spaces between variously shaped splinters, as it were, of hard matter arranged so as to form laminæ.

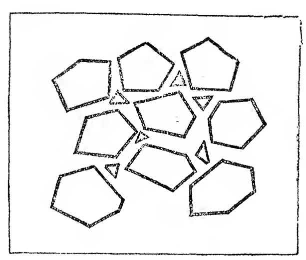
The transverse partitions in the tubes and calicles give evidence in their structure that they are later additions to the inside of an already formed tube. They are not merely transverse floors, but flat-bottomed cups of tissue fitted inside the old tube, and thus narrowing its bore considerably in the region where they become formed. The old boundary line of the tube below the tabula can nearly always be traced, continuing its course for some distance beyond and above the tabula (Plate 9. figs. 11, 15). The tabulæ of the cœnenchymal tubes seem in all respects identical in structure with those of the calicles.

The structures which form the centres from which the systems of hard tissue radiate have been called axes. They have the appearance of being canals in the hard tissue; but this appearance seems to be fallacious. They appear to represent the points of junction of the walls of the opposed cœnenchymal tubes where imperfect fusion has taken place between these walls, and the interspace has been filled with amorphous rather than fibrous calcareous matter. In some cases in transverse sections these axes appear as elongated spaces between the adjacent tubes, rather than central canals. The appearance of these axial structures is accurately represented in Plate 8. fig. 4. There is always a somewhat opaque, fine, granular area around them, which shows often a series of concentric zones.

The opaque tissue surrounding the axes is continued into the projecting points at the surface of the coral. These points sometimes show a banded appearance, as if they had received in growth successive caps of hard tissue (Plate 9. fig. 11, P).

### *On the Growth of the Corallum of* Heliopora cærulea.

If a rapidly growing tip of a frond of *Heliopora cærulea* be carefully protected from injury and macerated in potash, the appearance of its corallum will be that given in Plate 9. fig. 16. The tissue at the actual tip is seen to be much more delicate and spongy-looking than in the older parts. It consists here superficially of an aggregation of thin-walled cells, which are mostly multiangular in outline at their mouths, sometimes hexagonal, often pentagonal, often with curved sides, assuming these various forms apparently from mutual appressure in growth. In the angles where the walls of the adjoining cells meet are the commencements of new cells, which in their very earliest stage are often triangular in superficial outline (see diagram). Amongst this mass of polygonal cells new calicles are developed by the arrest in growth of one or more cells after they have reached a certain small height, which cell or cells form a central floor to the calicle. All around this central floor, contiguous, deeper, older cells form a circular zone. Their inner walls, *i. e.* those nearer to the centre of the growing calicle, cease to grow, and only their outer ones continue to develop; and these being fused together form the lateral walls of the calicle,



and the plications in the wall of the fully formed calicle are to a great extent* the result of this peculiar mode of growth. This will be understood by reference to Plate 9. figs. 16 & 17, and also to Plate 9. fig. 15, where at B a section of a newly formed calicle is given.

In a newly formed calicle, thus, the cavity is comparatively shallow in the centre, but prolonged at the bottom all round into a series of tubular offsets. Into these tubular offsets the mesenterial filaments hang down in the fresh condition of the animals. On further simple growth the tube of the calicle becomes elongated, and receives a new uniform bottom in the shape of a tabula. As the calicle approaches maturity, the cells immediately around it become nearly occluded at their mouths by increased development of calcareous matter at its margin. In older parts of the corallum the mouths of all the tubes are rendered very small by the excessive thickening of their walls and of the beams of hard tissue bearing the projecting points. On a quickly expanding frond of the coral the mouths of the series of cœnenchymal tubes, which are rapidly increasing, are disposed in almost regular straight or curved lines radiating towards the points of extension. In this condition the lateral walls of each line of cells frequently fuse, becoming common to the line and more developed and prominent than the transverse ones, and thus come to form long, delicate ridges with projecting points on their edges, running almost parallel to one another, and with troughs between them. In these troughs calicles may arise, being most irregular in outline at first, but gradually becoming shapely by taking in surrounding cells. In some cases the point-like prominences at the margins of the walls of the cells included within a newly formed calicle may be seen at the bottom of the calicle, maintaining a disposition parallel to that of the trough in which the calicle is formed.

These lines of calicles may be termed lines of growth. The calicles show a more or less marked disposition in transverse curves, cutting these lines at right angles.

The development of the *Heliopora* colony probably takes place somewhat as represented in Plate 9. fig. 15. The original calicle (A) increases in length and forms successive chambers, $A'$, $A''$, $A'''$, $A''''$, by developing tabulæ. It gives off a series of buds from its margin, which become elongate tubes divided into compartments in the same way, and in their turn give off buds. New calicles are formed as at B in the figure.

### *Formation of the Hard Tissue.*

Everywhere in the living portions of the coral applied to the surface of the hard tissues is found a layer composed of elongate connective-tissue cells. The cells are nucleate and are finely granular in appearance, and are frequently drawn out into fine filaments at the ends. These cells occur only in connexion with the hard tissue, excepting in the superficial layer of the mesoderm beneath the epidermis, Plate 9. fig. 10. In the median plates of the mesenteries, for example, where no calcareous

* Not entirely, sometimes two plications can be seen corresponding to one lateral tube only in a young calicle.

matter is formed, they are wanting, and homogeneous connective-tissue alone present. It seems hence almost certain that they are the instruments of formation of the calcareous tissue. The newly formed and growing points of the corallum yield much more organic remains after treatment with acids than the older portions. If one of these small points, after having been treated with a strong solution of potash, be examined under the microscope, it will show apparently no trace of consisting of any thing but the usual doubly refracting calcareous matter. If it be then slowly decalcified, an investing layer of finely fibrous tissue is gradually brought into view as the lime is removed. The fibrous tissue seems to form an investment to the hard part, or rather to be present only in its peripheral regions, the central part of the piece of corallum appearing to be free, or almost so, from contained fibrous structures, and thus to be more rapidly attacked and decomposed by the acid. In specimens of *Heliopora* which have been slowly decalcified in chromic acid, the appearance presented by one of these growing points as viewed from below is shown in Plate 8. fig. 6. Here it will be seen that a mass of tissue composed of extremely fine fibre (B) occupies the space immediately within the layer of connective-tissue cells. The fibres composing the mass are disposed in a concentric manner externally around the centre of the mass, and more internally around two rounded cavities situate side by side in its centre. Appearances similar to this are presented by a section of *Heliopora*, prepared as described, cut parallel to the surface and viewed from beneath, sometimes two and sometimes one cavity appearing in the fibrous mass. The fibrous masses occupy the position which in the undecalcified coral is occupied by the projecting points of the corallum, and are identical in structure with the small investment of fine fibrous tissue which can be obtained from a growing point of the corallum by decalcification. But the quantity thus derived from a portion of the corallum cleaned with potash is very small, and bears no proportion to the mass shown in fig. 6. The spaces A, B were probably occupied by the central parts of two newly formed excrescences on a projecting point of the corallum, whilst the hard tissue was extended thence for some distance amongst the fibrous tissue, but how far is uncertain. I have not been able to prepare sections of hard and soft parts in contact which will show this.

I have not seen the finely fibrous tissue in the deeper parts of the corallum; but in some preparations it is to be recognized in longitudinal sections, as at Plate 9. fig. 10, P, though here not showing the fibrous structure.

It seems probable that the layer of connective-tissue cells produces the finely fibrous tissues, and that within this tissue the calcareous matter is deposited from within outwards, the fibrous tissue gradually being removed and absorbed. The finely fibrous tissue may be termed calciferous. Exactly similar tissue with similar concentric fibrillation occurs in similar relations in *Pocillopora*, though here the connective-tissue cells are perhaps absent.

In no part of the growing points of the corallum of *Heliopora* is there any trace of the calcareous tissue being built up of the fusion together of a network of spicules, as

is the case in the corallum of *Corallium rubrum* and also in *Tubipora*, as may be seen at once by examining the growing end of the tube of a spirit specimen of *Tubipora**. In this respect *Heliopora* differs most markedly from both *Corallium* and *Tubipora*. The structure of the hard tissue of *Heliopora* is, however, in many respects very like that of the sclerites of *Primnoa*.

### *Blue Coloration of the Corallum.*

The corallum of *Heliopora* is coloured of a deep blue, and has always been regarded as remarkable amongst corals for this fact. Now that it is known to be an Alcyonarian structure the fact is less exceptional, since both *Corallium* and *Tubipora* have a deeply coloured corallum, and many other Alcyonarians have coloured spicules. Amongst Hexactinians *Stylaster*† *rosaceus* is of an intense red, and the corallum of some Fungias is also red; also that of certain Eupsammidæ, but amongst these the condition is exceptional.

The blue tint is seen in sections of the corallum to be diffused within the hard tissue. The colour is faint or almost absent in the freshly growing tips of the corallum, and pale in the most recently formed superficial structures generally; it is darkest in the layer beneath these in the recently matured tissue. In transverse sections it is seen to be darkest at the surfaces of the walls of the tubes and calicles. In vertical sections of the corallum the continuation of the dark blue line marking the margin of the wall of each tube enables the line of the tube to be traced past the superadded tabula, and marks the boundary between the two structures. Very exceptionally, intensely blue streaks are developed more internally on either side of the central canal, as in Plate 9. fig. 12, where B marks such a blue band. The usual distribution of the colouring is that shown in Plate 8. fig. 4, where the dark zone at the margin of each tube seen in section represents intense colouring. The tabulæ are almost colourless.

When the corallum is boiled for a long period in caustic potash the blue colour remains unaltered. When the calcareous matter is removed from the corallum by means of hydrochloric acid, the colouring-matter is set free, and remaining suspended in the fluid gives it a blue tint. It is, however, not in solution, but can be observed under the microscope to exist in the fluid in the form of small, amorphous, intensely blue masses adhering to small shreds of tissue, &c., and in this condition may be proved to be insoluble in strong hydrochloric acid. If the coloured solution formed by hydrochloric acid be filtered, the blue colouring-matter remains on the filter, and the filtrate has only a very slight greenish tint.

* This fact concerning *Tubipora* seems not to be well known. CLAUS, *l. c.* p. 204, says: "Unter Ausschluss von Kalkkörpern entstehen endlich die festen Kalkskelete der Tubiporen und sämmtlicher Madreporarien." The fact was well known, however, to Professor WYVILLE THOMSON, who directed my attention to it. Prof. THOMSON does not know, however, where the fact is published (he thinks possibly by Prof. PERCEVAL WRIGHT in the 'Ann. and Mag. of Nat. Hist.'). Disks of soft tissue spread from the mouths of the tubes of growing parts of the coral. The disks contain an open network of calcareous matter, evidently composed of fused spicules. The disks fuse with neighbouring ones and form the horizontal laminæ.

† Since the above was written I have proved the Stylasteridæ to be Hydroids.—*July* 8, 1876.

The colouring-matter is dissolved at once off the filter by alcohol, and an intensely blue solution, very like that of sulphate of copper in colour, is thus obtained. The colour, however, is not dissolved out of the corallum by the action of alcohol alone. The deep blue and alcoholic solution gives a spectrum in which all the violet, red, and yellow are totally absorbed, and the green and blue alone transmitted. The absorption of the violet end of the spectrum extends to G, that of the less-refrangible end to a little short of E. Addition of potash or ammonia solutions to the blue solution changes the colour to a dirty green, which is contained in a flocculent precipitate. The blue colour reappears on the solution being rendered again acid.

In BRONN'S 'Klassen und Ordnungen,' 1860, "Actinozoa," p. 22, is an account of the analysis made by the younger SILLIMAN, at the request of DANA, of various coralla. Amongst the species analyzed was *Heliopora*. Mr. SILLIMAN therefore probably investigated the colouring-matter of this coral at the time when he submitted it to analysis.

### *On the Structure of the Soft Tissues of* Heliopora.

The arrangement of the structures constituting the general superficial layers of *Heliopora*, and of those common to the cœnenchymal tubes and calicles, will be considered in the first place, and in the second the structure of the polyps themselves.

As in other Alcyonarians the various structures are to be classed as belonging to an ectoderm, mesoderm, and entoderm. The general arrangement of these three layers of tissue will be seen in Plate 8. fig. 1.

The *ectoderm* consists of a layer of epithelial cells, which invests the whole external surface of the coral with a uniform covering. Its structure is shown in Plate 9. fig. 10. The cells composing it are elongate and club-shaped, with wide rounded summits and pointed lower extremities, which run out into fine threads which can be traced some way into the layer beneath them. The cells contain a nucleus and nucleolus, and their general contents are finely granular; they are closely packed side by side, placed parallel to one another, and vertically to the surface of the coral. When the epithelial layer is viewed from above, the ends of the cells present a series of polygonal areas. The cells are about ·02 millim. in length. Between the contracted bases of these cells are other irregularly shaped cells with similar nuclei and contents, and also scattered throughout the layer are to be found nematocysts. The ectoderm is prolonged to form the lining of the stomachs of the polyp; otherwise it is superficial only.

The *mesoderm* consists of three different histological structures:—(1) A nearly homogeneous transparent connective-tissue; (2) layers of connective-tissue cells; and (3) masses of finely fibrillar tissue.

(1) Beneath the ectoderm is a thick layer, of a mean thickness of about ·07 millim., likewise extending over the whole surface of the coral, which consists of a highly transparent connective-tissue, which is almost homogeneous, but in which faint lines indicating slight fibrillation may here and there be seen.

Extensions of this homogeneous layer form the central layers of the membranes

lining the cœnenchymal tubes and calicles, and the median plates of the mesenteries, part of the wall of the stomach, &c. The layer immediately beneath the ectoderm is pierced by the superficial system of canals and traversed by the projecting points of the corallum, Plate 9. fig. 10. Nematocysts occur in this last-mentioned layer. They are extremely small, measuring only ·009 millim. in their longest diameter. They are of an ovoid form, and contain a single filament within wound in a spiral whose axis corresponds to the long axis of the cell. They are often to be seen with the thread emitted and twisted in a loop against the side of the cell, which frequently assumes after the ejection of the thread a reniform outline, Plate 9. figs. 13, *b*, *b'*. They are so small that they might readily be overlooked, and a very high power is required to determine their structure. They appear to be not very abundant. They are seen *in situ*, Plate 9. fig. 10, N.

(2) Imbedded within the superficial homogeneous layer of the mesoderm occur also fusiform and branched connective-tissue cells, which are associated together in elongate, often nearly linear groups, Plate 9. fig. 10. Many of these cells are branched, throwing off fine filamentous processes in various directions. Layers of similar cells lie everywhere next opposed to the hard tissues of the living corallum, as has already been described. These cells do not compose any portion of the polyps themselves, but merely line the calcareous calicles.

(3) In decalcified preparations of *Heliopora* enclosed within the layers of connective-tissue cells, at the places before occupied by the growing points of the corallum, occur the masses of very finely fibrillar calciferous tissue already described, Plate 9. fig. 10, P. Both this and the corallum itself belong to the mesoderm.

The *entoderm* consists of spherical cells, each with small transparent nucleus and contents, consisting of irregular yellow pigmented masses and dark coarse granules. They have a mean diameter of about ·014 millim., but vary much in size. They are most probably ciliated in the fresh condition, as are the closely similar entodermic cells of other Alcyonarians. I have not been able to see cilia in the hardened specimen which I have examined; nor have I in these specimens been able to detect differences between the entodermic cells lining the cavities of the calicles and tubes and those lining the canals. Some of the cells show a division of their contents into four (Plate 9. fig. 13, *a*, *a'*). The entodermic cells form layers lining the canals, the cœnenchymal tube-cavities, the cavities of the calicles, and interseptal spaces.

The cœnenchymal tubes in their upper cavities are thus lined throughout by a membrane consisting of three layers, viz. an outer layer of connective-tissue cells, a middle layer of homogeneous connective-tissue, and an inner lining layer of entodermic cells. The calicles are lined throughout in like manner. The arrangement will be seen in Plate 8. fig. 4. In the membrane lining the calicles, in transverse sections a peculiar structure (shown Plate 8. fig. 3) is to be constantly observed. Stout offsets from the median connective-tissue layer pierce the outer layer of connective-tissue cells, and hang loose externally as flattened tags, which appear as if broken off, and are

often somewhat curled up. I have been unable to determine the connexion of these tags of tissue with the calicular wall, Plate 8. fig. 3 *. Beneath the uppermost tabulæ scarcely any organic lining remains to the tubes, if any at all, and the deeper central parts of the corallum are, in the specimen of *Heliopora* which I have examined, almost entirely filled with the tubes of the boring annelids (*Leucodora*, sp.). Thus when a mass of *Heliopora*, after being hardened, is decalcified, the whole of the deeper parts are removed, and a thin layer of soft tissue only remains behind, which above presents a similar appearance to that of the surface of the undecalcified coral, but beneath is seen to be composed of a series of villi with the bottoms of the calicular sacs appearing as tubercles amongst them. Since the tubes of the cœnenchym and calicles have no lateral connexions with one another except close to the surface of the corallum, in decalcified preparations they are, excepting at their very upper extremities, entirely separated from one another; hence it is extremely difficult to prepare fine transverse sections in the deeper regions, since the structures afford no support to one another.

*Canal-systems.*—The summits of the cavities of the sacs of soft tissue lining the cœnenchymal tubes communicate freely with one another and with the cavities of the polyps by means of a system of short transverse canals, which cross over the margins of the walls of the calcareous tubes at the lower parts of their mouths, as already described, p. 97, and shown, Plate 9. fig. 7. The tubes are mostly very short; they are circular in section, and have the same three layers in their walls as have the sacs within the tubes. In older parts of the coral, where the calcareous tubercles on the surface are much developed and the mouths of the cœnenchymal tubes contracted, a series of open channels appear in the corallum at the bases of the superficial papilliform eminences, when the coral is looked at with a hand-magnifier. It is in these channels that the system of transverse canals runs. This canal-system I have termed the "deep canal-system," to distinguish it from the system of smaller canals lying superficially to it. The tube-cavities communicate with the polyp-cavities by means of the transverse canal-system, through a system of large apertures shown in Plate 9. fig. 8. These apertures open in the intermesenterial spaces all around the summit of the calicle, a single one being situate in the space formed by each externally projecting fold of the calicular wall.

The superficial canal-system consists of a series of small canals and sinus, which take mostly a more or less vertical direction, and communicate directly with the deep canal-system. These superficial canals anastomose with one another by horizontal offsets. A series of horizontally extended canals of this system surrounds each contracted polyp, the canals taking a radial arrangement. One such canal is shown in vertical section in Plate 9. fig. 7, and the appearance of the summits of the canals as seen from the surface of the coral is shown in Plate 8. fig. 5. The superficial canals are not only lined by, but also always more or less filled with entodermic cells.

* Exactly similar structures occur in *Tubipora*, being specially developed around the lower part of the polyps.

Openings to the exterior other than those of the polyps were carefully sought for over the surface of *Heliopora*, but without success. The spots from which, by decalcification, growing tips of corallum have been removed, often form themselves into apertures in horizontal sections, and are apt to mislead the observer.

### *Structure of the Polyps of* Heliopora.

The polyps of *Heliopora* have been examined by me only in a contracted condition.

When the contracted polyps are viewed from the interior they show (Plate 8. fig. 5) eight symmetrically and radially disposed lobes, separated by deep sulci corresponding to the insertions of the eight mesenteries into what would be, in the expanded condition of the animal, part of the lateral wall of the polyp. The lobes show a distinct striation in the direction of their length, indicating probably the presence of fine muscular fibres in their substance. At their inner region the lobes show, near their common centre, a number of extremely small nuclei upon their surface. The lobes just described form a covering closing the mouth of the calicle.

From the centre of the disk of lobes a tubular cavity, which may be called the atrium, leads down directly to the mouth (Plate 8. fig. 1); and around the mouth and just above it orifices of the eight tubular introverted tentacles open into the atrium. The tentacles in the retracted condition are completely introverted and appear as tubes, the inner cavities of which would, in the expanded condition of the polyp, form the outer surface of the tentacle. The cavities of the introverted tentacles communicate directly with the atrium, as may be seen in vertical sections, by orifices which show in the centre a cruciform lumen (Plate 8. fig. 1, T′) formed by the folds of the ectodermic lining of the tentacular cavity. The retracted tentacles are directed at first horizontally outward from the atrium, and then turned downwards at nearly right angles to their former course. The tentacles rest in the intermesenterial spaces. Transverse sections of four of them are seen in Plate 8. fig. 3. The cavities of the introverted tentacles are lined by a direct continuation of the ectoderm, which passes down over the inner surface of the atrium to enter these cavities. In their interior it is elevated into a series of short stout tubercles, which no doubt project much more in the expanded condition of the tentacle, rendering it compound as in other Alcyonarians. In the tentacles, as seen in Plate 8. fig. 3, three layers, outer entodermic, median connective-tissue, and inner ectodermic, can be readily distinguished. The median probably contains muscular structures, but I have been unable to see them.

The stomach of *Heliopora* is closely similar to that of other Alcyonarians. As seen in the contracted condition its walls are horizontally plicate. In transverse sections, as Plate 8. fig. 3, the layers composing its walls are well seen. There is the usual covering of the entoderm; but in the mesoderm, within the layer of homogeneous connective-tissue, a second narrow zone (B, fig. 8) can be detected, which is probably muscular. The inner ectodermic lining is continuous with that of the tentacles, but ciliate. Eight mesenteries completely divide the upper part of the cavity of the polyp

into eight radially disposed chambers. The mesenteries consist of a median plate of homogeneous connective-tissue, which is directly continuous with the similar layer of the lining membrane of the calicular cavity, and also with that surrounding the stomach, and of an investment of entodermic cells covering the median plate on both sides, excepting where the retractor muscles intervene between the two. These retractor muscles form the lower borders of the mesenteries; they consist of long stout fibres which, lying on the surface of the mesenteries, take origin from the lower part of the sides of the polyp-cavity, reaching down sometimes as far as the margin of the tabula, and curve inwards and upwards, becoming gradually more concentrated as they ascend to be inserted round the mouth and region just below it, in the intervals between the bases of the tentacles.

The muscles have in position, with regard to the plates of the mesenteries, the same arrangement which KÖLLIKER has described as existing in the Pennatulidæ, and which has also been found in the genus *Umbellula* by LINDAHL and figured ("Om Pennatulidslägtet *Umbellula*," till Kongl. Vet. Akad. inlemnad den 10. Feb. 1874: Stockholm, tab. 1. fig. 8)*.

The arrangement of the muscles is seen in Plate 8. fig. 3, where R M, R M are the muscles. At opposite ends of the long axis of the stomach the muscles are on opposite sides of the mesenterial plates. The mesenterial chamber (seen beneath in the drawing), which is free of muscles, is the "Dorsalfach" of KÖLLIKER; the opposite one the "Ventralfach." The muscles are covered by the entodermic layer, and are in direct contact with the median plates of the mesenteries, being modifications of the mesoderm.

I have not been able to find any definite protractor muscles in *Heliopora*. I have, however, occasionally seen fibres on the surface of the mesenteries at the lateral margins of the atrium, coming apparently from the stomach-wall, which may prove to be such. In transverse sections I have seen no trace of such muscles.

*Heliopora* having commonly twelve so-called septa and eight mesenteries, a definite and regular relation of the eight septa to the twelve plications of the wall of the calicle might naturally be looked for; none such, however, exists. As has been before stated, the number twelve is by no means constant; and where twelve are present the arrangement varies in all kinds of ways. In Plate 8. fig. 3 the plications are shown in a section, and their relations are accurately copied. Here there may be counted either twelve or thirteen such plications, representing corresponding calcareous septa in the indentations.

There are eight mesenterial filaments, as usual, present, which spring from the angle where the retractor muscles are inserted into the stomach-wall, and are continued down the free borders of the muscles, being attached to them. The filaments have the usual structure. Two filaments appear to be constantly longer than the others;

* Professor SCHNEIDER and M. RÖTTEKEN must certainly have been mistaken in their conclusions concerning the arrangement of the muscles with regard to the mesenteries in Alcyonaria, if the figure given in the 'Ann. & Mag. Nat. Hist.' 1871, vii. p. 437, as representing them be correct.

but I am uncertain about this point, it being very difficult to get a view of all the filaments uninjured in any one polyp. To which sides of the mesenterial plates the filaments are attached I have not made out.

Out of at least a hundred polyps examined from the colony of *Heliopora* hardened for examination, only three were found to contain generative organs; in each of the cases ova. In two of the polyps a single ovum only was present, in the third four ova attached singly to four mesenteries. The ova are attached to the edges of the muscular margins of the mesenteries at a point about halfway between the origin and insertion of the fibres composing the lower border of the muscle (Plate 8. fig. 1). The ovum is attached to this border by a specially developed mass of entodermic cells, and at its point of attachment is in close relation with the mesenterial filament. The ova, as shown (Plate 9. fig. 14), are large, measuring ·21 millim. in diameter (the smallest observed measured ·17 millim. in diameter); they are composed of an outer membranous capsule, by means of which they are attached in position, containing a mass of yelk-globules, in which lies a germinal vesicle and germinal spot.

It was not determined which of the mesenteries bore ova, or whether those with long filaments bore them or not, the expectation that abundance of fertile polyps would be found for examination having been disappointed. In Plate 8. fig. 1 the mesenterial filament is, in the drawing, stopped short above the ovum in order to allow it to be seen. The filaments belonging to the septa bearing ova hang down below the ova. No trace of any male elements was found in any polyp. The colonies of *Heliopora* are probably unisexual.

The investigation of the positions of the dorsal and ventral aspects of the polyps in the *Heliopora* colony relatively to the axes of growth is extremely difficult, because when a horizontal section is cut sufficiently deep down to display the muscular arrangement, nothing remains to hold the various sections of polyps in position but the imbedding substance made use of; and where the only substance at command, as in the present case, is wax, the sections with the wax unremoved are almost too opaque and indistinct for observation. By examining such sections, held together by the wax and made transparent with glycerine, I have found that the polyps (although they are often turned on their central axes to a considerable extent, so that the long axes of their stomachs are not by any means parallel, but often inclined to one another at very considerable angles) have nevertheless their dorsal surfaces or the intermesenterial spaces devoid of retractor muscles ("Dorsalfächer") always nearer to the summits of the colony than are the "Ventralfächer." The "Dorsalfächer" thus show a general tendency to take a superior position, *i. e.* lie uppermost, in the vertical plates of which the colony is composed. The entire coral makes up a flat plate, with two outer surfaces, towards which the polyp-tubes are directed in curves on either hand from the vertical axis of growth; and the polyps thus curving away from one another have their "Dorsalfächer" approximated or are placed back to back.

*On the Structure of* Sarcophyton, *sp.*

An Alcyonarian dredged in shallow water amongst the reefs on the shores of the Admiralty Islands was examined in order to compare its structures with those of *Heliopora*. The Alcyonarian in question appears to belong to the genus *Sarcophyton* (LESSON) M.-EDWARDS and HAIME ('Hist. Nat. des Coralliaires,' t. i. p. 122), originally described in the 'Zoologie du Voyage de la Coquille,' Zooph. p. 92 (1831). The genus is stated by M.-EDWARDS to be imperfectly known. The specimens correspond in every particular with the description as given by M.-EDWARDS. The Alcyonarian has exactly the form of a mushroom, with a cylindrical stem and polyps confined to the upper surface of the pileus. Many specimens were obtained, but unfortunately only one retained for dissection, the remainder being packed away.

In this specimen the pileus is about 5 centims. in diameter, being somewhat oval in outline; the height from the bottom of the stem to the summit of the pileus is also about 5 centims.; the diameter is about 1·5 centim. The colony is of a uniform brown colour.

By CLAUS (*l. c.* p. 208) a genus of the Alcyoninæ, called also *Sarcophyton*, is given as founded by SARS. I do not know whether the old genus *Sarcophyton* has been abandoned and the name used again, or whether there is some error here. The form now under consideration certainly belongs to LESSON'S genus, and possibly to the species *lobatum*. On examination the *Sarcophyton* was found to present many points of interest, especially in comparison with *Heliopora*; a short description of its anatomy will therefore be given.

As in Pennatulids two kinds of individuals, sexual and asexual, polyps and zooids, compose the *Sarcophyton* colony. The stem of *Sarcophyton* consists of a series of tubular canals running parallel to one another vertically, and bound together by abundant transparent connective-tissue, in which are closely packed, numerous, stout, calcareous spicules of the common elongate cylindrical form, pointed at both ends, and covered with small lateral tubercles. The canals are prolongations of the polyp-cavities from above. The surface of the stem and under surface of the pileus are covered with an even coat of epidermis, and entirely free from polyps or zooids. On the upper aspect of the pileus the surface is covered all over with polyps or zooids. Over the general upper surface the polyps are pretty evenly distributed at intervals, the inter-spaces being filled by numerous zooids; but at the margin of the pileus, where its edge is turned down and slightly recurved, is a narrow zone all round, occupied by thickly set polyps with very few zooids. In a vertical section through the central axis of the whole colony, the polyp-tubes are seen to be arranged with great regularity, converging in curved or vertical lines, according to position, towards the stem. The circular areas occupied by the retracted polyps measure 1·4 millim. in diameter, those occupied by the zooids ·42 millim. in diameter—the difference in dimensions being here much less than in deeper regions of the colony, where the polyp-cavities widen

and the zooid-cavities contract. There are narrow intervals between the circular areas, in which there project the thickly set tips of spicules showing through the epidermis (Plate 9. fig. 9) and forming stiff supports to the walls of the cavities.

The structure and relations of the zooids and polyps are seen in Plate 8. fig. 1. The polyps present no remarkable features; they have numerous fine spicules in their antennæ, which are, as is usual, simply retracted, and are provided with protractor and retractor muscles. Of the protractor muscles (P M in fig. 2) part of the fibres appear to be inserted into the wall of the polyp-cavity, whilst others are continued on the inner borders of the mesenteries.

The muscles are arranged with regard to the septa as in *Heliopora*, Pennatulids, and *Umbellula*, showing a dorsal and ventral intermesenterial space; and here the protractor muscles were seen to be placed on the opposite sides of the mesenterial plates to the retractors. Two mesenterial filaments are longer than the rest; probably they are those of the "Dorsalfach," since the only two retained by the zooids are the dorsal ones. The ova are developed deep down in the polyp-cavities; they have the usual form of the ova of Alcyonarians. They measure, when mature, about 7 millims. in diameter. They are placed in Plate 8. fig. 2 at a greater height up in the cavity of the polyp than that at which they usually occur. Ova are to be found in the tubular prolongations of the polyp-cavities very deep in the colony.

The polyp-cavities widen out beneath the surface to contain the polyps and gradually contract again below; they have an extreme diameter of about 2 millims. against a diameter of about ·35 millim., which is that of the tubular cavities of the zooids. The zooid-cavities are only about one fifth the length of the polyp-cavities. The zooid-cavities contract below, and their tubes gradually narrowing join the canal-system, as is described by Kölliker to be the case in *Sarcophyllum* (Kölliker, *l. c.* 1te Abth. Taf. viii. fig. 68). The zooids (Plate 9. fig. 9) consist of a simple globular stomach lined within by a thick epithelium, a prolongation of the ectoderm, and communicating with the exterior by a narrow tubular mouth; they have no trace of tentacles. The inner surface of the stomach is covered with long cilia, directed downwards and inwards. Near the surface of the body, just beneath the ectoderm, eight mesenteries are present in all the zooids; but four of these extend to a much less depth than the others, and hence in a horizontal section at a very slight depth from the surface all the zooids in section are seen with only four mesenteries. The four deeper mesenteries are those attached to the ends of the long axes of the stomach, *i. e.* the dorsal and ventral. Only two mesenterial filaments are developed in the zooids, and these are those of the dorsal mesenteries. The filaments are attached throughout their length to the margins of the septa. The zooids are without sexual organs. The body is covered with an ectoderm resembling in structure that of *Heliopora*; but it was not sufficiently well preserved in the available specimen to show its exact structure. No thread-cells were found in the *Sarcophyton*. The mesoderm forms a sarcosome consisting of tongh, gelatinous, transparent connective-tissue, in which are distributed,

somewhat sparsely, very small finely ramified nucleate corpuscles. In the walls of the zooid- and polyp-cavities there is to be seen a transverse fibrillation of a part of their mesodermic layer; and the wall, when seen in section on edge, shows a layer next the cavity of the polyp or zooid consisting of true transversely directed fibres.

The sclerites or spicules are imbedded in the thick layers of the sarcosome intervening between the zooid- and polyp-cavities and between the tubes composing the stem, besides being found in the tentacles. The growing tips of the spicules project up amongst the ectodermic cells (Plate 9. fig. 8), carrying with them their investment of connective-tissue. When the spicules are removed by acid, corresponding cavities are left in the mesoderm. A transparent membrane can be distinctly seen investing closely each spicule; no structure, however, could be seen in the membrane. The polyp- and zooid-cavities, and the whole of the canal-system, is invested as usual by an entodermic layer, consisting of spherical cells with yellow contents exactly like those of *Heliopora*. In the zooid-cavities, at their summits, around the top of the stomach, masses of these cells were always observed to be accumulated. Possibly the accumulation of these in this situation is consequent on action taking place on the death and contraction of the colony when placed in spirits.

*Sarcophyton* is an extremely favourable subject for the examination of the vascular system. In sections from alcoholic specimens preserved in glycerine jelly the whole ramifications of the vessels are most clearly displayed. Owing to the pigmentation of their lining entoderm, the canals show out dark and defined in the perfectly transparent connective-tissue. The arrangement of the canals is shown in Plate 8. fig. 2.

Two systems of canals are to be distinguished—the transverse and vertical systems. The transverse canals run parallel to the surface of the colony and to one another in each interspace between the polyp-cavities. They take the most direct courses to connect the cavities of the polyps with those of the surrounding zooids and with those of the adjacent polyps. They commence to be given off laterally from the polyp-cavities at their very summits, forming there communications with the zooid-cavities. They continue to be given off at tolerably regular intervals, crossing now to a closely situate zooid, now to a distant one. Deeper down in the colony the canals make long stretches to join the next adjacent polyp-cavity, and become shorter and shorter as the polyp-cavities converge below. Similar short canals connect the zooid-cavities with one another. Running in a general vertical direction between these transverse canals are the vertical canals, distinguished by their more undulatory course. The chief stems of this system of canals are the direct prolongations of the zooid-cavities. In connexion with these canals is an irregular meshwork, by which the whole deep connective-tissue is permeated, and through the meshes of which the transverse canals pass. Offsets of the vertical canal-system pass between the zooid-cavities, and between the polyp-cavities and zooid-cavities give off transverse connecting branches.

There is no surface network of canals present in the superficial layer of mesoderm directly beneath the ectoderm as there is in *Heliopora*.

The large canals in the stem of *Sarcophyton*, which are in reality long drawn-out prolongations of the body-cavities of the polyps, may be considered to correspond to Kölliker's "sinus;" the vertical and transverse canal-systems to the "canales nutrici majores;" the network in connexion more directly with the vertical system to the "vasa nutrica minora." Apparently there are no vessels corresponding to the "vasa capillaria," their place being occupied by the network formed by the small ramified corpuscles in the sarcosome.

The transverse and vertical canal-systems anastomose with one another frequently, but only here and there. Occasionally, but rarely, the canals from the bottoms of the zooid-cavities join directly the transverse canals. The canals have a wall of fibrous tissue directly continuous with the fibrous layers of the zooid- and polyp-cavities, and are lined internally by entodermic cells, Plate 9. fig. 9, C. Sac-like enlargements or swellings are constantly to be seen on the canals of *Sarcophyton*, both near the surface and in the deep tissue. In one such swelling was found a parasitical cyst of oval form and with greenish contents; its nature could not be determined. The polyps in *Sarcophyton* are so disposed that they have the dorsal intermesenterial spaces directed towards the centre of the pileus, and at the verge of the pileus these spaces uppermost. At least this disposition was observed to hold good in three opposed radial directions from the centre of the pileus. A whole specimen was not available for examination.

As in *Heliopora* the polyps are not disposed with perfect regularity in this manner, so that radial lines from the centre of the pileus would pass directly through their longer diameters. Many of them are rotated more or less on their axes, so as to be inclined to the radial lines. They are most regular in disposition at the margin of the pileus. The zooids, though preserving a general uniformity of arrangement, which proves their single pair of mesenterial filaments to be the dorsal ones, are still more irregular in disposition.

### *Notes on the Structure of two Species of* Millepora.

I have examined the structure of two species of *Millepora*; one, *Millepora alcicornis*, was obtained at Bermuda, the other species was found at Zamboangan, Mindanao, Philippine Islands. The investigation of the structure of the genus *Millepora* is beset with unusual difficulties. The calcareous tissue of the coral is very hard and compact, and the soft tissue, on the other hand, very soft and very much altered and shrunk by the action of spirit. Further, the polyps are extremely small. I give here only a few results at which I have arrived from the examination of the material which I have at present at command. I hope to obtain abundance of *Milleporæ* at Hawai and Tahiti, and to make a thorough investigation of their structure.

The corallum of *Millepora*, although in its histological structure it resembles *Heliopora* very closely, being formed of a similar fibro-lamellar tissue, differs extremely from *Heliopora* in the coarse arrangement of its components. Instead of being composed of a series of parallel tubes divided by tabulæ, the corallum of *Millepora* is composed of a net-

work of tortuous branches of hard tissue, with cavities of two kinds, smaller and larger. In *Millepora alcicornis* the calcareous meshwork is comparatively open. In the Philippine species, in which the polyps are extremely minute, the cœnenchymal tissue is much more compact—so much so that instead of, as in *M. alcicornis*, the hard and soft parts appearing to form equally complicated meshworks, the soft tissues appear to occupy a series of tortuous canals bored in the compact cœnenchym; and in finely ground sections these canals becoming filled with *débris*, and thus as it were injected with opaque matter, stand out black in relief when the sections are viewed by transmitted light, and show the relations of the hard to the soft parts in a very clear manner. The tortuous tubes channelled in the hard cœnenchym are seen to lead from the calicles in all directions, and anastomosing freely with one another to join the cavities of surrounding calicles.

When a mass of *Millepora* hardened in alcohol is decalcified, a thin layer, consisting of almost the entire living substance of the coral, separates from the surface, and, as the only residue of the deeper tissues, a greenish gelatinous mass remains. The superficial layer thus separated consists of an irregular network of tortuous canals, which in the recent state occupied the canals in the hard cœnenchym or were interwoven with its equally complex meshwork. The canals are filled with round cells, resembling the endodermic cells of Alcyonarians; their walls are thickly beset with the large thread-cells, which have already been described and figured by Professor AGASSIZ. The cells are ovoid, and are provided with a long filament armed near the end with a spiral of spines. The thread-cells are developed in special large transparent sacs, and are seen in all stages of formation. Two kinds of thread-cells are present, the larger ones just described, and others of nearly the same form, but of not more than one fifth the length, which small thread-cells are confined to the tentacles, on the surfaces of which they are densely set. The larger thread-cells are especially abundant round each polyp, forming a zone around it. The canals are covered externally with a transparent tissue, probably calciferous in function. In certain places in the *Millepora* obtained at Zamboangan here and there canals larger than the others, chief stems as it were, are to be found running a long straight course on the surface for an inch or more, and giving off branches on either side. Canal offsets of the general meshwork join the polyp masses all around in a radiate manner. The larger polyps, as seen from above, have an irregular indented outline, whilst the smaller are simply circular or nearly so. The larger are less numerous than the small. Tentacular masses covered with the smaller thread-cells can be seen in the apertures of the polyps of both kinds. Their number could not be determined with certainty, since it is impossible to define the exact limits of the contracted lobulate masses and distinguish a mere lobe of a tentacle from an entire tentacle. In the larger polyps, however, there constantly appeared to be four. Professor AGASSIZ saw and figured four tentacles only in *Millepora alcicornis*. POURTALÈS says that the tentacles appeared to him "rather as tentacular masses studded with lasso-cells, five in number." From the appearances which present

themselves in fine vertical sections of the polyps of *Millepora alcicornis*, I think I cannot be mistaken in the conclusion that the tentacles of the polyps are compound, consisting of a broad central portion provided with five or six short pinnæ on either side. Such tentacles might well appear as tentacular masses if not quite fully expanded*. The tentacles are simply retracted. The layer of cells covering their exterior is continuous with that lining the cavity into which they are retracted, and ectodermal in character. In vertical sections in *Millepora alcicornis* the stomachs of the polyps are seen to be cylindrical in form, but drawn out and widened below by the action of retractor muscular fibres which are attached around their bases. The stomach-cavity is lined with very large, inflated, transparent, cylindrical cells. The stomach has externally to this a fibrous or muscular wall, which is again covered externally, as are the tentacles, by a layer of cells reflected from the wall of the cavity in which it is retracted. In transverse sections the stomach has its lining cells sometimes so arranged as to show an exactly cruciform central opening between them, the outline of the stomach being quadrangular, with the points of the cross directed to the angles, in other cases the opening is three-rayed. The retractor muscular fibres attached to the stomach are seen, on viewing the organ in horizontal sections from beneath, to radiate out from its margin all round, and to be attached to the cœnenchymal canals, which, as before described, likewise radiate from the polyp masses. The fibres often pass a considerable distance along the canals before they are lost to view. The radiating muscular fibres, which are fine and transparent, are gathered here and there into bundles, and sometimes appear as if arranged in a regular radiating system. Fibres are present radiating at slightly different depths all round the circle. No trace of radially disposed mesenteries has been detected in *Millepora*, though fine transverse sections have been obtained. No continuous ectodermic layer covering the outer surface of *Millepora* has been found; such must be present, but it has only been observed indistinctly in fragments in *M. alcicornis*, where it is extremely delicate. The specimens of both species of *Millepora* obtained were without generative organs.

The greenish mass left behind as representing the internal structures of the Zamboangan species of *Millepora* after decalcification is extremely delicate and transparent. It was only observed in the *Millepora* obtained at Zamboangan, where its green tint rendered it conspicuous. The green tint on examination of the mass with a high power is found to be caused by a tangle of the filaments of a vegetable organism which bores the hard parts of the coral in all directions, and of a slight transparent residue from the decalcified corallum.

## *Notes on the Structure of* Pocillopora, *sp.*

A species of *Pocillopora*, possibly *P. acuta*, was obtained at Zamboangan. A pre-

* *July* 8, 1876.—Since the above was written I have found that these appearances are due to the presence in the smaller zooids of large numbers of short knobbed tentacles, which become massed together in the retracted condition of the zooid.

liminary examination of its structure gave the following results:—The histological structure of the corallum of *Pocillopora* differs from that of *Heliopora* and *Millepora* in that its hard tissue is composed of definite prisms of calcareous matter, the polygonal ends of which prisms can be seen when the systems in which they are disposed are viewed end on. The prisms further show a transverse banding, appearing something like that of transversely striped muscular tissue. The corallum is excessively hard and compact.

When the coral is decalcified, a very thin continuous membrane separates from the surface with the entire structure of the polyps disposed within it at intervals. The membrane shows little structure, consisting, as it does, of a thin epithelial ectodermic layer and of a layer of connective-tissue. It is devoid of thread-cells and of any canals or vessels. Beneath it shows small masses of concentrically wound fine fibres, where the projecting points of the corallum have rested, just as in *Heliopora.*

The polyps have very shallow cavities, as necessitated by the form of the corallum. They have twelve tentacles, six intermediate ones of which are smaller than the others. They have the usual twelve mesenteries, and have long mesenterial filaments coiled up in the intermesenterial spaces, though how many of these filaments are present is uncertain.

The specimen of *Pocillopora* examined was devoid of generative organs. The deep tissue of *Pocillopora,* when decalcified, yields a delicate gelatinous mass, showing very ill-defined structure, but full of the same vegetable parasite as that which attacks *Millepora.* A further examination of *Pocillopora* will be made at Hawaii.

It has already been stated that Professor VERRILL discovered some time ago that *Pocillopora* was a Hexactinian; but I do not know to what extent he carried his examination of the coral.

### *Note on the Structure of a* Stylaster.

Since KUNTH, as already stated, has referred to the covering of the mouth of the calicle of *Cryptohelia* as the analogue of the operculum of the Rugosa, I may state that I examined a specimen of a Stylasteracean dredged by the 'Challenger' in 500 fathoms off the Meangis Islands on February 10th, 1875, and with the same result arrived at by SARS in his examination of *Allopora oculina* (SARS, *l. c.*). The Stylasteracean in question is exactly similar in every respect to *Cryptohelia pudica,* excepting that it has no calcareous laminæ in front of the mouth of its calicle.

The tentacles are of a dirty green colour, simple, elongate conical in form, and, as in the case of *Allopora oculina,* they lie *in the grooves between the calcareous septa* and are retracted and protruded in these grooves. The calcareous septa are twenty-two in number, and the tentacles also twenty-two.

The coral when decalcified leaves an organic residue, consisting of an extremely open network of tissue very similar to that of *Millepora.* The network forms a very soft and feeble mass, having the form of the hard parts, the place of which latter is

occupied in part by transparent connective-tissue. From the circle of tentacles a cylindrical cavity, showing twenty-two plications on its wall, leads to the stomach. The stomach is globular, with a long conical mouth or proboscis projecting up in the centre of the last described cavity. A similar proboscis is described by SARS as existing in *Allopora oculina*. The stomach seems to have no outlet below; but it is of course difficult to be certain of the fact in so small and yielding a structure. A series of bundles of fibres, each bundle continuous with one of the plications of the cavity above, is attached to the periphery of the stomach. There are no mesenteries, at least none so distinctly differentiated histologically that they can be recognized by methods which show them plainly in *Heliopora* and *Pocillopora*. Fine transverse sections of polyps stained with carmine were obtained; they showed only the open meshwork of tissue around the stomach, but no definite mesenteries. In the part of the meshwork surrounding the cavity leading from the tentacular circle to the stomach, and just below the level of the tentacles, lie the generative organs. All the individuals of the only stock of *Stylaster* examined were males; hence these corals appear to be diœcious. Very large globular sacs crammed with spermatic cells, containing some of them vesicles of evolution, and others masses of spermatozoa spirally wound, were found in the position above described, attached to parts of the meshwork, and disposed sometimes in a single row around the calyx, sometimes in two rows one above the other. These occupy the interior of the cavities of the ampullæ. No trace of mesenterial filaments was seen in *Stylaster*.

Portions of a *Cryptohelia* examined showed an exactly similar structure to that of the *Stylaster* *. The *Cryptohelia* stock also contained only male generative elements.

### *Notes on the Parasitic Vegetable Organisms found in* Millepora *and* Pocillopora.

The hard tissue of both the *Millepora* and the *Pocillopora* from Zamboangan are traversed in all directions by fine capillary branching canals, bored by some low vegetable organism. The canals are provided at intervals with numerous spherical cavities attached to them laterally, and obviously having contained in the fresh state the spore capsules of the organisms.

The *Pocillopora*, which has an unusually dense and hard corallum, is most thoroughly permeated by three parasites; the Zamboangan *Millepora*, in which the tissue is dense, has them to a somewhat less extent; whilst in the *Millepora alcicornis* from Bermuda, in which the corallum is comparatively soft and cancellar, borings of the parasites can only here and there with difficulty be detected.

The parasites, when set free by acids, are seen to be composed of a ramifying mycelium with abundance of fructification. The parasites are probably similar in nature to those described as infesting the shells of mollusca and other hard animal tissues by Professor KÖLLIKER and Dr. CARPENTER, references to whose papers on the subject have already been given. I have seen also a paper on the vegetable parasites in shells

* *July* 12, 1876.—I have since shown that the whole of the Stylasteridæ are true Hydroids.

in the 'Proceedings' of one of the learned societies of Vienna—I think in the 'Sitzungsberichte.'

A remarkable fact is that the parasites are distinctly green, though they appear to be fungi, and those of shells are described as fungi. Possibly the parasites in question have already been described by Professor KÖLLIKER. I have, of course, not access to his paper*.

[POSTSCRIPT.—Received November 25, 1875.

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Since writing as above and since sending off my paper to the Royal Society, I have come upon a passage in the 'Voyage autour du Monde de l'Astrolabe: Zoologie,' QUOY et GAIMARD, vol. iv. Zoophytes, pp. 252, 253 (Paris, 1832), which is to the following effect:—

M. DE BLAINVILLE'S observations on the animal of *Heliopora cærulea* led him to remove it from the genus *Pocillopora*, in which it had before been placed, and form the genus *Heliopora* for it, because the *Pocilloporæ* have never more or less than twelve tentacles.

*Heliopora* has either 15 or 16 short, broad, triangular, pointed tentacles, forming a disk around the mouth. The animals were made out with difficulty with a powerful lens. (Eight compound tentacles have evidently been mistaken for sixteen simple ones.)

Formerly QUOY and GAIMARD mistook, on the voyage of the 'Uranie,' the expanded parasitic *Leucodoras* for the polyps of *Heliopora*. They call them small parasitical zoophytes, probably of the class of Annelids.

At p. 245, QUOY and GAIMARD describe the twelve short tentacles of *Pocillopora damicornis*. The nature of the polyps of *Pocillopora* was therefore well known long before Prof. VERRILL'S examination of them †.]

## CONCLUSIONS.

*Heliopora* is most undoubtedly an Alcyonarian. The number of its mesenteries, and the distribution with regard to them of the retractor muscles, the form and number of its tentacles, are decisive evidence in the matter; and this evidence is borne out by almost every item of histological structure. In the peculiar manner in which the retraction of the tentacles takes place, viz. by introversion, *Heliopora* seems to differ from

* Since the above was written I have found the same parasites in various corals from all parts of the world.

† Received February 28, 1876.—In the nurse-stocks of several species of *Fungia* a kind of intracalicinal gemmation appears to take place. On the separation of a young free *Fungia* from the nurse-stock, the next free *Fungia* buds out from the centre of the scar left on the stem, *i. e.* from what has once been the centre of the calicle of the stock. (See SEMPER, Generationswechsel bei Steinkorallen.) I have lately found a very fine specimen of the nurse-stocks of a large species of *Fungia* at Tahiti, and have been able to see this fact quite plainly. It is owing to this mode of growth that the stems of the nurse-stock become jointed.

all other Alcyonarians except *Corallium**. From both *Corallium* and *Tubipora*, *Heliopora* differs in that the hard tissue of its corallum shows no signs of being composed of fused spicules, but in its histological structure most closely resembles Zoantharian Corals. With the Milleporidæ and with the Pocilloporidæ and Seriatoporidæ *Heliopora* is allied solely on account of its possession of tabulæ. Now that an Alcyonarian is added to the list of various Anthozoa possessing these peculiar structures, their presence becomes of less classificatory importance even than Professor VERRILL proved it to be. There can hardly be a doubt that *Seriatopora* will prove to be, like *Pocillopora*, a Zoantharian; and *Millepora* is certainly very different in structure from *Heliopora*. *Heliopora* thus stands quite alone amongst modern forms; and in the peculiar structure of its cellular cœnenchym it is so remarkable that it is unlikely that on examination of the soft parts of other corals, at present known from their coralla only, any near relatives of it will be discovered. Amongst extinct forms, however, *Heliopora* has several close allies, and the genus itself existed in the Cretaceous period. The genus *Polytremacis* differs apparently only in the more perfect development of the so-called septa, which reach to the centres of the tabulæ. The genus occurs in the Chalk, Greensand, and in Eocene formations. *Heliopora* has, further, a very closely allied palæozoic representative in *Heliolites*, in which the cœnenchymal tubes are provided with very closely placed tabulæ.

The three genera *Heliopora*, *Polytremacis*, and *Heliolites* differ from one another in so slight a degree that they are placed under the one genus *Heliopora* by QUENSTEDT. To include these three genera, a new family of Alcyonarians must be formed, for which the term Helioporidæ appears most suitable, which family may from the recent species be thus characterized:—

### Family HELIOPORIDÆ.

A compact corallum present, composed of a fibro-crystalline calcareous tissue as in Madreporaria. Corallum consisting of an abundant tubular cœnenchym, and with calicles having an irregular number of lateral ridges resembling septa. Calicles and cœnenchymal tubes closed below by a succession of transverse partitions. Polyps completely retractile, with tentacles when in retraction introverted. Mouths of the sacs lining the cœnenchymal tubes closed with a layer of soft tissue, but communicating with one another and with the calicular cavities by a system of transverse canals.

The structure of the cœnenchym of the Helioporidæ is entirely unique amongst Anthozoa; no other form has a cœnenchym composed thus of a series of long tubes packed side by side, and lying parallel to the calicular tubes and at right angles to the surface. It is to be remarked that the tubes are like the calicles in being open above,

* I have found no information on this point in any of the text-books; but in SCHMARDA's 'Zoologie' there is a figure of *Corallium*, copied from LACAZE-DUTHIERS's 'Hist. Nat. du Corail,' in which the tentacles are drawn introverted as they are in *Heliopora*.

that they have walls composed in exactly the same manner as those of the calicles, and that they are closed below at intervals in the same way by exactly similar tabulæ. Further, the soft tissues lining the cavities of the cœnenchymal tubes are identical in structure with those lining the calicular cavities, and the same transverse system of canals connects the summits of the tubes with one another and with the summits of the calicular cavities.

It seems by no means improbable that the cœnenchym here is composed of the tubes of absorbed polyps or zooids which have lost the rudimentary organs, which they still possess in such a form as *Sarcophyton*, and have become mere tubular cavities, whose openings to the exterior even have been obliterated; it seems impossible otherwise to account for the presence of the successions of tabulæ in the cœnenchymal tubes. The foregoing considerations are suggested by the circumstance that a series of fossil corals, grouped by M.-EDWARDS under the Tabulata, appear most probably to have been Alcyonarians as well as *Heliopora.*

The genus *Chætetes* was considered by KEYSERLING to have belonged to the Alcyonarians, because of the absence of septa in it, and the mode in which its polyps are grouped; but MILNE-EDWARDS retains it amongst the Zoantharians, because of its close resemblance to the Favositidæ, in which the presence of septa is regarded as conclusive in deciding against Alcyonarian affinity. The presence of calcareous septa, however, must now be considered a character of less importance than it formerly was. As is seen in the case of *Heliopora* pseudo-septa may exist, which do not necessarily correspond in any way, in disposition or number, with the membranous mesenteries. In *Stylaster* and *Cryptohelia* the calcareous septa are obviously formed as infoldings of the margin of the calicles. Here the septa are between, instead of opposite to the tentacles; and membranous mesenteries appear to be absent, or at all events rudimentary only. In the Favositidæ the septa seem to have been no more perfect than they are in *Heliopora*, and to have been most variable in number, but often twelve, as also in *Heliopora.* M.-EDWARDS describes from 10 to 12 septa in *Favosites gothlandica.* In *Michelinia favosa* 30 to 40 subequal septal striæ are to be made out at the upper margin of the wall of the calicle. I cannot refer to specimens; but it seems not unlikely that the septa in the Favositidæ were pseudo-septa as in *Heliopora*, and that these coralla were formed by Alcyonarians, the perforations in the walls having transmitted transverse canals like those of *Heliopora* and *Sarcophyton*, and the coralla being free of tabular cœnenchym, because none of the polyps were aborted as in *Heliopora.* Some Favositidæ seem to have formed a compound colony, consisting of polyps and zooids, as *Favosites Forbesii*, where a few large cells are seen set amongst numerous surrounding small ones. *Heliolites* seems to a certain extent to form a transition stage between a condition such as that in *Favosites Forbesii* and the condition in *Heliopora*; for in *Heliolites*, the more ancient form, the cœnenchymal tubes are regularly hexagonal, and apparently much more nearly equal in breadth to the calicles than in *Heliopora.* In the growing points of *Heliopora* the hard parts are made up of a series of open, often hexagonal tubes, and resemble *Favosites* in their surface aspect. In *Heliopora* the transverse canals pass over

notches in the summits of the walls of the cœnenchymal tubes and calicles, in order to place these cavities in communication with one another. In *Favosites* the calcareous tissue surrounded the transverse canals, and the perforations in the walls of the calicles were thus produced.

If *Favosites* was an Alcyonarian, *Chætetes* was of course also of that group. The genus *Alveolites* amongst the Favositidæ is peculiar for the possession of three tooth-like prominences as the only representatives of septa. One tooth, well developed, is situate inside the calicle; on that side of each calicle which lies externally in the colony, and opposed to this on the tip of the calicle next the interior of the colony, are a pair of rudimentary teeth. This arrangement reminds us at once of the distinction of dorsal and ventral mesenterial interspaces in Alcyonarians, and the direction of all the "Dorsalfächer" in *Sarcophyton* and *Heliopora* towards the central axis of the colony. In *Alveolites* the two teeth seem to correspond to the "Dorsalfach," and the single one to the "Ventralfach," the two teeth having occupied the space devoid of retractor muscles. KÖLLIKER describes a series of teeth as existing at the margin of the calicle in *Renilla*, which follow a constant law in their relation to the septa. When only one tooth is present it is opposite the "Dorsalfach;" when three, one is opposite the "Dorsalfach," and the two others opposite the lateral "Ventralfach." In *Alveolites* the one tooth is ventral instead of dorsal. In *Syringopora* the septa seem to be very much of the same nature as in *Heliopora*; and in *Heliopora*, as already described, the tabulæ are not merely transverse floors, but the bottoms of cups of hard tissue fitted inside the older tubes and calicles. In *Syringopora* this condition of the tabulæ is much more marked, and the corallum appears as if formed of a series of calicles fitted one within another.

A difficulty appears to arise from the peculiar mode of the development of the calicles by budding in *Heliopora*, the foldings of the walls of the calicles being due, to a considerable extent at least, to the formation of these walls from a circle of cœnenchymal tubes. The septa are, however, not entirely formed in this way. It would of course be of great interest to see whether the primitive calicle, in the developing *Heliopora* colony, forms calcareous septa.

*Heliopora* having so commonly twelve septa, and in conjunction with these eight mesenteries, it was at first thought that here some key would be found to the elucidation of the question of the relations of the tetrameral corals to the Hexactinians; but no definite arrangement of the eight mesenteries to the twelve septa could be discovered. LUDWIG and POURTALÈS have concluded that the tetrameral condition in the Rugosa is the result of a modification of an originally hexameral arrangement—that the Rugosa are, in fact, modifications of the Hexactinian type. KUNTH, however, using similar methods, has come to an opposite conclusion. Now that it is known that an Alcyonarian exists which constructs a solid calcareous corallum, in histological structure scarcely, if at all, to be distinguished from that of many Madreporaria, and that this Alcyonarian also possesses marked calcareous septa, which septa show, notwithstanding

the octameral arrangement of the mesenteries, a hexameral disposition, in being often twelve in number, it seems that the question of the affinities of the Rugosa may fairly be reopened. The presence of well-marked calcareous septa in *Cryptohelia* and other Stylasteridæ (which septa are equal to the tentacles in number, but nevertheless to be regarded, like those of *Heliopora*, as pseudo-septa) is significant. The marked tetrameral arrangement of the septa in Rugosa, and the presence in many forms of tabulæ, are certainly characters not opposed to the alliance of these corals with the Alcyonarians; and the fact that paired series of opercula occur in certain Rugosa, which are compared by LINDSTRÖM, their discoverer, to the skeletal structures of certain *Primnoæ*, seems to be evidence in favour of such an alliance of the very strongest kind. In no Madreporaria do paired hard structures, at all resembling those of *Primnoæ* or of *Goniophyllum pyramidale*, occur. The opercular structures in the coralla of *Cryptohelia* and *Lepidopora* can scarcely be regarded as comparable with the opercula of Rugosa. The structures are merely folds of the lip of the calicle, and are continuous with it and immovable, not movable separate articulate structures. Many Rugosa show an arrangement which may well be compared to the distinction of dorsal and ventral regions in Alcyonaria. The most important distinctive character of the Rugosa appears to be the occurrence in them, alone of all Anthozoa, of intracalicinal gemmation *.

With regard to *Sarcophyton*, the fact that compound colonies composed of multitudes of zooids, combined with a lesser number of sexual polyps, occur amongst the Alcyonidæ, as well as amongst the Pennatulidæ, in which they are so well known from KÖLLIKER'S great work, appears to be new to science. That in such colonies and in *Heliopora* the "Dorsalfächer" are all turned towards the axis of the colony and directed upwards is also a new fact. The zooids in their structure seem to conform very closely to those of Pennatulids (*Sarcophyllum*, e. g.); but to the list of distinctive differences between the zooids and polyps of Pennatulids given by KÖLLIKER, viz. the absence in the zooids of tentacles, the presence of two mesenterial filaments (the dorsal ones), the absence of generative organs, and the shortening of the hypogastric region to such an extent that it fuses with the anastomosing canal-system—to these marks of distinction must be added, in the case of the zooids of *Sarcophyton*, the fact that four of the mesenteries, the dorsal and ventral pairs, are deeper than the others.

It seems extremely difficult to reconicle the extraordinary succession of the mesenteries in the development of the Zoantharians, discovered by LACAZE-DUTHIERS, with the facts presented by Alcyonarians. Did the development of the eight mesenteries of Alcyonaria correspond with that of the first eight mesenteries formed in Actiniadæ, the first mesenteries formed would be either the lateral dorsal or lateral ventral; but these are those which are most rudimentary in the zooids of *Sarcophyton*. Moreover the mesenterial filaments of the two lateral pairs of septa are in the development of Actiniadæ the first to appear, and not the dorsal, which are longest in the Alcyonarian polyps and

* An examination of the Cornulariadæ, the only recent solitary Alcyonarians, might very possibly throw light on the question of the affinities of the Rugosa.

most persistent in the zooids. Apparently, however, development in Alcyonarians follows a different course.

In *Halysceptrum*, the development of which has been examined by KÖLLIKER, the eight mesenteries appear from the very first. In *Kalliphobe* (BUSCH), one of the *Edwardsiæ*, according to METSCHNIKOFF, the larva has, in its earliest stage, eight tentacles and two mesenterial filaments.

The peculiarities presented by the Stylasteridæ have struck many observers. M.-EDWARDS and HAIME placed these corals (Stylasteracea) under the Oculinidæ. GRAY, however, established a family (Stylasteridæ) for the genus *Stylaster* alone. POURTALÈS, who in his 'Deep-Sea Corals' dwells upon the many peculiarities of the corallum of this family, places under it the genera *Allopora*, *Stylaster*, *Distichopora*, *Cryptohelia* *, *Lepidopora*, and *Errina*. The peculiarities in the structure of the soft parts, and the relations of the tentacles to the septa, described in this paper as occurring in a *Stylaster* and a *Cryptohelia*, and the similar facts observed by SARS in the genus *Allopora*, strengthen the facts brought forward by POURTALÈS, with regard to the coralla, in a very potent manner. I hope to make a close study of the structure of *Stylaster*. The apparent absence of mesenteries is most remarkable, and a similar condition appears to occur also in *Millepora*. The number of tentacles and septa in the Stylasteridæ seems hardly to follow the usual hexameral law. In the species of *Stylaster* examined by me there are invariably twenty-two septa and twenty-two tentacles. In *Stylaster erubescens*, POURTALÈS describes the septa as being in number from nine to twelve, most frequently eleven. In *Allopora miniata* the septa are from seven to ten, generally eight. *Cryptohelia* has commonly sixteen.

With regard to the affinities of the Milleporidæ, no certain conclusion can be arrived at from the few facts yet ascertained. I hope to obtain specimens at Hawaii in sexually mature condition †.

H.M.S. 'Challenger,' North Pacific.
21st July, 1875.

* POURTALÈS has remarked that the genus *Endohelia* of M.-EDWARDS and HAIME appears indistinguishable from the genus *Cryptohelia* of the same authors. *Endohelia* is founded on a Japanese species. The 'Challenger' dredged a coral certainly not generically distinguishable from *Cryptohelia* off the coast of Japan.

† POSTSCRIPT.—Since the above was written I have been able to refer at Honolulu to Prof. LACAZE-DUTHIERS's 'Histoire Naturelle du Corail.' I therefore add a few notes.

In *Corallium* the contracted polyp presents externally at the surface eight lobes coloured red. When the polyp is expanded, these lobes form a coloured cup with eight dentations at its margin, which surrounds the lower part of the expanded colourless polyp (see pl. 2 of Prof. LACAZE-DUTHIERS's work). The eight lobes described as closing the mouth of the calicle in the contracted polyp of *Heliopora* probably occupy a similar position, and have a similar appearance in the expanded condition of the polyp.

In *Corallium* the pinnæ or barbules of the tentacles are all severally introverted (*l. c.* p. 57), as well as the tentacles themselves. In *Heliopora* this appears not to be the case. In the hard tissue of *Corallium* boring vegetable parasites occur, as observed in *Millepora* and *Pocillopora*.

I have further been able to refer to DANA's great work on Corals in the splendid collection of scientific works in the Government Library at Honolulu, and to other works relating to *Heliopora*.

## Description of the Plates.

Illustrating the structure of *Heliopora cœrulea* and *Sarcophyton*, sp.

All the drawings, with the exception of figs. 16 & 17, Plate 9, are by the author of the paper. Figs. 16 & 17, Plate 9, are by Mr. J. J. Wilde.

### PLATE 8.

Fig. 1. Schematic representation of a section vertical to the surface of *Heliopora cœrulea*, showing the relations of the hard to the soft parts: the hard parts are coloured dark. In the centre is seen in section a fully developed sexually mature polyp in a retracted condition. The calcareous calicle in which it is contained is closed beneath by the tabula (CT), and the walls of the calicle are continued above into points (P) projecting above the general surface of the coral, the section being supposed to be so carried as to pass through two of the calcareous projections which surround the calicle.

Closely applied to the surfaces of the calcareous tissue, and lining its cavities everywhere, is a layer of spindle-shaped connective-tissue cells, between which and the layer of entodermic cells is an interval occupied by transparent homogeneous connective-tissue.

The layer of epithelium (E) covering the whole surface of the coral is seen to be continuous with that covering the exterior of the tentacles (here, from the introversion of those organs, appearing as their interior), whilst the entodermic layer (EN) covers their interior. The tentacle on the right side of the drawing has its tip passed behind the retractor muscle,

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Dana states (U.S. Expl. Exped. vol. vii. Zoophytes, J. D. Dana, Philad. 1846, p. 539) that the blue colour of *Heliopora* is of animal origin and is lost on immersion of the coral in nitric acid. The colouring-matter was not analyzed by Mr. Silliman.

In the Atlas of the 'Voyage de l'Astrolabe,' Zoophytes, pl. 20. figs. 12, 13, 14, the expanded polyps of *Heliopora cœrulea* are figured by MM. Hombron and Jacquinot. In fig. 14 sixteen very short, simple, conical tentacles are shown, in fig. 13 only fifteen tentacles. The figures are evidently very erroneous. The corresponding description I have been unable to refer to, the volume containing it being wanting in the Hawaiian Government copy.

In the Zoology of the 'Voyage de l'Uranie,' Quoy and Gaimard, Paris, 1824, p. 656, is a description of the polyps of *Heliopora* (*Pocillopora*) *cœrulea*.

The expanded polyps have radiated tentacles, and are said to entirely hide the corallum when they are in an expanded condition. Experiments proved that the communication between the animals is somewhat imperfect, since a stimulus applied to any part of the colony caused only the polyps in that immediate neighbourhood to retract themselves.

In the plates of the 'Voyage de l'Uranie,' pl. 96. figs. 5, 6, 7, *Heliopora* is figured, showing in fig. 5 the appearance of the coral in the fresh state, but without any representation of the polyps.

notwithstanding the actual continuity of the muscle with the mesentery above, in order to show the position of the ovum (O). At the bottom of the atrium, *i. e.* the central canal leading from the mouth and tentacles to the exterior, and formed by the deep retraction of the animal, are shown the mouths of the tubes formed by the introversion of two tentacles as they appear when looked directly into.

On the right-hand side of the figure three tubular cavities (TC, TC, TC), forming the so-called cœnenchym, are represented, lined by their soft tissues, composed of the same three layers as compose the lining of the calicle. Two of the tubes communicate above, over their lateral wall, by one of the deep canals. On the left-hand side of the figure portions of the plates of hard tissue forming the lateral walls of the tubular cavities are shown (A, A), with their natural upper margin. Two systems of canals are seen in section near the surface of the coral. The most superficial canals (V, V, V) lie almost immediately beneath the external epithelial layer; they are more numerous and much smaller than the deeper canals (V′, V′), which form communications between the adjacent tubular cavities passing over the summits of the lower parts of their walls, as is seen on the right-hand side of the figure. Both sets of canals are lined with entodermic cells.

A A. Portions of the walls of the tubular cavities.
CT. Calcareous tabulæ.
P. Projecting points of calcareous tissue.
E. Epithelial layer of ectoderm.
EN. Entodern.
C. Layer of homogeneous connective-tissue.
D. Layer of connective-tissue cells.
T. Tentacles introverted, seen in longitudinal section.
T′. Tentacles introverted, viewed directly into their mouths.
S. Cavity of stomach.
RM. Retractor muscle.
MF. Mesenterial filament.
TC. Tubular cavities of cœnenchym.
V. Superficial smaller vascular canals.
V′. Deep larger vascular canals.

Fig. 2. Section vertical to the upper surface of *Sarcophyton*, sp., showing three sexual polyps and a number of zooids.

The polyps are represented in the contracted condition; they occupy three large elongate cavities in the general transparent sarcosome. The tentacles here are not introverted simply but retracted. The sarcosome between the polyp-cavities is traversed by an elaborate network of canals belonging to two systems, a transverse one, and a vertical one, which, how-

ever, freely anastomose. The transverse canals lead directly from one polyp-cavity to another, with a course nearly parallel to the surface plane of the *Sarcophyton*, or from the polyp-cavities to the zooid-cavities. The vertical system of canals has a tortuous, branching, freely anastomosing course. The zooid-cavities contract at their lower extremities, and pass directly into this system of canals. Prolongations of the vertical system of canals pass up to the surface between the zooid-cavities, and between these and the polyp-cavities.

Z. Zooids.

PM. Protractor muscle.

RM. Retractor muscle.

C. One of the canals of the transverse system.

Fig. 3. Transverse section across a polyp of *Heliopora cærulea*, taken just below the mouth (decalcified). The tips of four of the tentacles cut across are retained *in situ*; the other four have fallen out.

D. External layer of connective-tissue cells.

C. Layer of homogeneous connective-tissue giving off a series of stout offsets (A), which pierce the layer (D) and project externally. This layer is seen to form the central plate of the mesenteries and a wall around the stomach.

EN. Entoderm lining the whole of the intermesenteric chambers.

M. Mesenteries.

RM. Retractor muscles. The "Dorsalfach" of Kölliker lies below in the drawing, the "Ventralfach" above. The muscles are covered by the entoderm.

TT. Tentacles cut across.

S. Stomach. B. Its muscular layer.

Fig. 4. Section parallel to the surface of *Heliopora cærulea*, to show the relation of the hard parts to the soft.

TC, TC and the similar oval spaces represent tubular cavities of the cœnenchym cut across. The interspaces between these cavities are occupied by the hard tissue.

The hard tissue is fibrous in structure, the fibres radiating from a series of axes here seen cut across (C). Suture-like lines (S) occur occasionally where the peripheries of the various radiating systems join.

D. Layer of connective-tissue cells.

C. Layer of homogeneous connective-tissue.

EN. Entodermic layer.

Fig. 5. Polyp of *Heliopora cærulea* and the immediately surrounding structures as viewed in a thick horizontal section from the outer surface.

The outer epithelial layer is not seen, being too transparent. The superficial projecting points of the hard tissue of the corallum are opaque, and are shown shaded dark. Away from the calicle the points are arranged in parallel rows. All over the surface are seen the tops of the ramifications of the superficial system of canals or sinus (V, V, fig. 1); those immediately around the polyp-lobes have a radiate arrangement. These canal-cavities are lined with entodermic cells.

In the centre of the drawing are seen the eight lobes of the contracted polyp with the mouth of the atrium in their centre. In their peripheral region the entodermic lining of the cavities of these lobes is seen showing through their superficial tissue.

Each of the lobes further shows a fine longitudinal striation, probably caused by muscular fibres, and very small nuclei at its inner aspect.

P. Projecting points of the corallum.

AA. Sinus of the superficial canal-system.

L. Lobes of contracted polyp.

Fig. 6. Portion of a section of *Heliopora cœrulea* parallel to the surface and viewed from beneath. From a specimen decalcified in chromic acid. The drawing represents a spot where a growing point of the corallum has been removed by the acid.

EN. Entodermic layer.

C. Homogeneous connective-tissue layer.

D. Layer of connective-tissue cells.

B. Very finely fibrous mass from which the calcareous tissue has been removed.

A. Cavity in the mass.

## PLATE 9.

Fig. 7. Diagram to show the canal-systems in connexion with the summits of the cœnenchymal tubes and calicles.

A. Cavity of a calicle.

B. Cavity of a tube.

D. Walls of these in longitudinal section.

The canals of the deep system (V, V′) lead over the summits of the walls from one tube to another, and from the tubes to the calicular cavities. The canal (V′) opening into the calicular cavity in the figure corresponds to the opening (O) in fig. 8.

C. A similar canal leading into a tube behind B.

Above is seen the superficial canal-system, consisting of smaller canals and sinus communicating with the deep canals and roofs of the cœnenchymal

tubes and laterally with one another. They have usually a vertical course. Their summits are seen in Plate 8. fig. 5.

Fig. 8. Transverse section through the uppermost part of a retracted polyp of *Heliopora cœrulea*, as viewed from below, showing the under surface of the most superficial structures closing the mouth of the calicle, *i. e.* the immediate under surface of the polyp-lobes seen in Plate 8. fig. 5 and Plate 9. fig. 7. The drawing is from a decalcified preparation. The soft parts lining the wall of the calcareous calicle are cut through; they retain the form of the calicle, to which they were closely applied. The wall presents a series of longitudinal folds so as on transverse section to show a sinuous outline with twelve indentations separated by twelve bulgings. The indentations occupied in the fresh condition of the animal by calcareous matter represent the twelve ridge-like calcareous septa present in the calicle. The indentations are neither in form nor arrangement symmetrical, nor are the eight mesenteries (M M) arranged symmetrically with regard to them.

Between the mesenteries the body-wall of the polyp does not reach outwards everywhere the entire distance to the wall of the calicle, but is continuous with this only in the region of its indentations. At each of the bulgings of the wall a wide aperture is left, by which the cavity of the polyp communicates with the canal-systems around.

M M. Mesenteries.

O O. Openings by which the polyp-cavity communicates with the canal-systems. The light oval spaces shown in the shaded areas of the openings are the sinus of the superficial canal-system.

Fig. 9. Vertical section through one of the zooids of *Sarcophyton*. On the left-hand side of the drawing the calcareous spicules are shown *in situ*. On the right the appearance presented after these have been removed by acid is shown.

The points of the spicules accompanied by a layer of connective-tissue project up far into the epithelial layer, raising it up just as the points of hard tissue in *Heliopora*. The connective-tissue shows excessively small ramified cells scattered through its otherwise homogeneous tissue. Portions of adjacent zooid-cavities are shown on either side of the central one; the transverse fibrillation of their wall is indicated.

Sp. Spicules.

S.C. Cavities from which spicules have been removed by acid.

S. Stomach of zooid provided within with long cilia directed inwards.

ME. Its mesenteries.

MF. Mesenterial filaments.

C. Canal of the transverse system, forming a communication between two adjacent zooid-cavities and lined by entodermic cells continuous with the layers lining the zooid-cavities.

EN. Entoderm.

C. Canal cut transversely.

Fig. 10. Portion of the superficial structures of *Heliopora cærulea* as viewed in a thin vertical section.

E. Ectoderm, consisting of elongate club-shaped cells running out below into fine processes, which traverse the next succeeding layer (M) of homogeneous connective-tissue. At the bases of these cells are cells of similar structure but irregular form. Small nematocysts lie amongst the epithelial cells, and some of them (N) are shown in the deeper regions. At EN the wall of one of the tubular cavities of the cœnenchym is seen in section at its edge, showing its three layers and the residue of animal matter (P) left by parts of its calcareous wall after decalcification.

Between EN and the section of the wall of the canal (V′) a narrow strip of the inner surface of the tubular cavity is viewed from its surface aspect.

E. Epithelial layer.

M. Layer of homogeneous connective-tissue.

N. Nematocysts.

C. Connective-tissue cells.

V. Canal of superficial system.

V′. Canal of deep system.

EN. Entodermic cells.

D. Layer of connective-tissue cells.

P. Residue of tissue after decalcification of a portion of the wall of a cœnenchym-tube.

Fig. 11. Section vertical to the surface of the corallum of *Heliopora cærulea*, showing the structure of the hard tissue.

A. Former calicle-cavity shut off from A′ the recent calicle of the tabula, C.

The tube-cavities on either side have similar tabulæ developed in them. In some of the tubes their walls are shown as cut parallel to their surfaces, in other places the cut edges of the walls only are seen.

The tabulæ being applied against the already formed insides of the calicles and tubes as a later formation, the line of the old wall of the calicle can always be traced up for some distance past the level of the tabula, which appears as the bottom of a second tube fitted within the first. The fibres forming the walls of the tubes &c. are inclined upwards and outwards at a uniform angle from the vertical axes.

A. Former; A′, recent calicular cavity.

C. Tabulæ.

B. Portion of wall of tube cut parallel to its surface, showing a line of suture between the fibres of opposite systems composing it.

D. Vertical canal.

P. Point of growing coral, showing lines of successive growth.

The numbers indicate the order in which the successive chambers were formed.

Fig. 12. Portion of the hard tissue forming the wall of a tube-cavity of *Heliopora cœrulea*, from the same preparation as fig. 11, more highly magnified.

C. Axis.

B, and similar shaded bands on the other side of the axis. Part of the tissue stained of a more intense blue than the remainder.

Fig. 13. *a*, *a*. Two of the cells of the entoderm of *Heliopora cœrulea*; one of these with the contents undergoing fission.

*b′*. Nematocysts of the same.

*b*. A form in which they are commonly to be observed, with the thread partly protruded and curved in a loop, and with one side of the cell bulged in.

Fig. 14. Ovum of *Heliopora cœrulea* as attached to the mesentery.

Fig. 15. Diagram to show the growth of *Heliopora* by successive budding and development of tabulæ.

A. The original calicle of the stock: A′, A″ &c., successively formed chambers in continuation of this calicle; 1, 2, 3, successive buds.

B. Formation of a new calicle. A short tube buds out, but the tubes on either side of it grow more quickly. Only the outer part of their walls continues to be developed; hence a wide calicular cavity is formed with the original short tube at its bottom.

Fig. 16. Drawing by Mr. J. J. Wildé, Artist to the 'Challenger' Expedition, of a rapidly growing tip of a frond of *Heliopora cœrulea.*

The young growing tubes of the cœnenchym are polygonal in area.

A A. Calicles in various stages of formation.

Fig. 17. A calicle nearly fully developed, as seen when looked directly into. The calicle is surrounded by irregular dentations, of which there are more than twelve. A circlet of cœnenchymal tubes is seen to join the cavity of the calicle below.

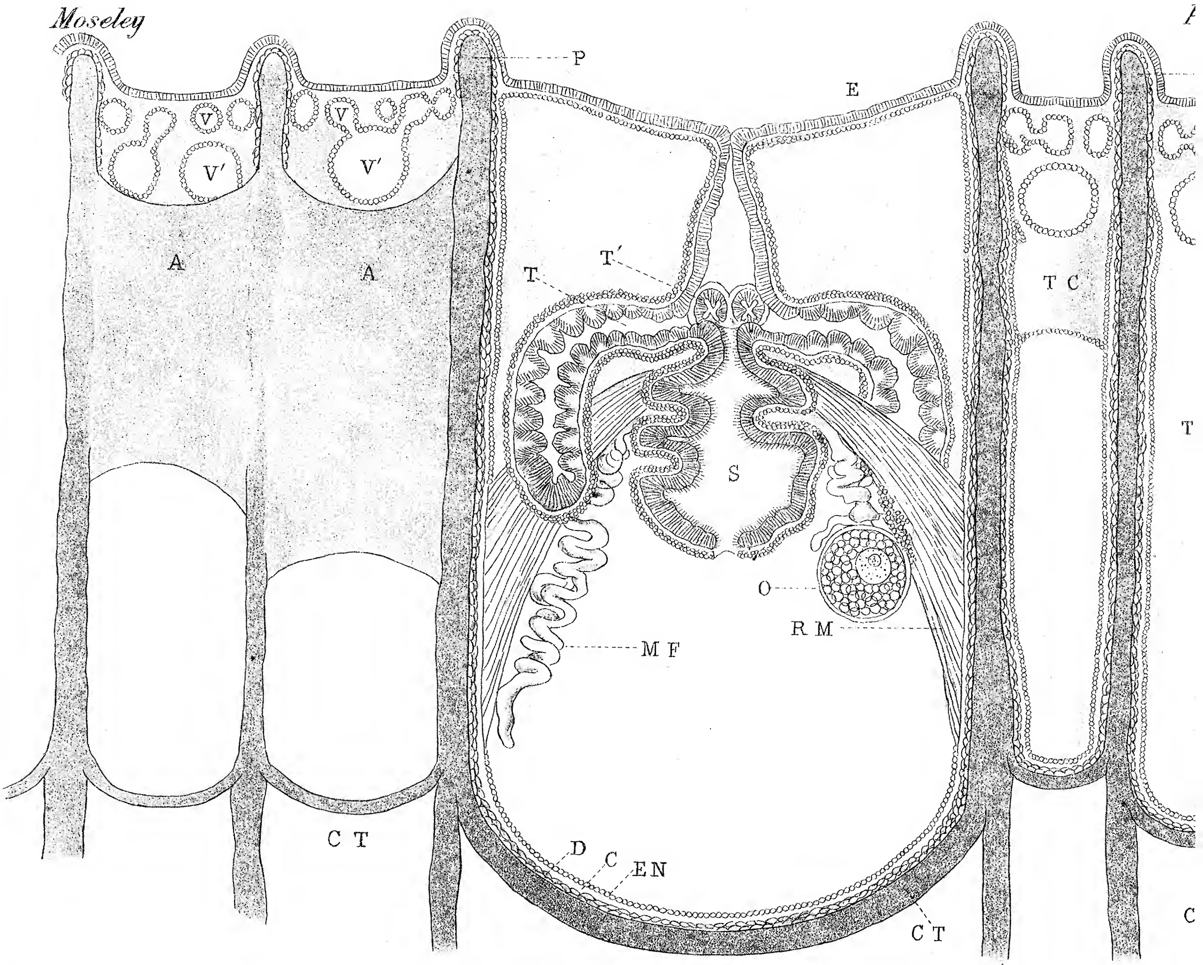



Fig.1. × 42 diameters

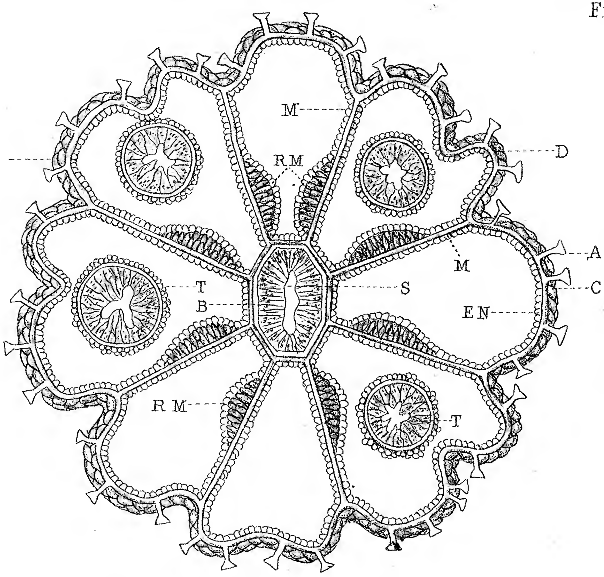



Fig.3. × 50 diameters

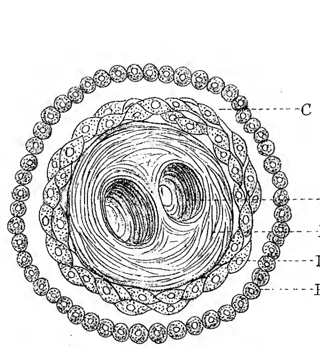
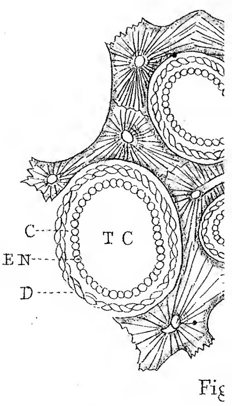



Fig. 6. × 200 diameters

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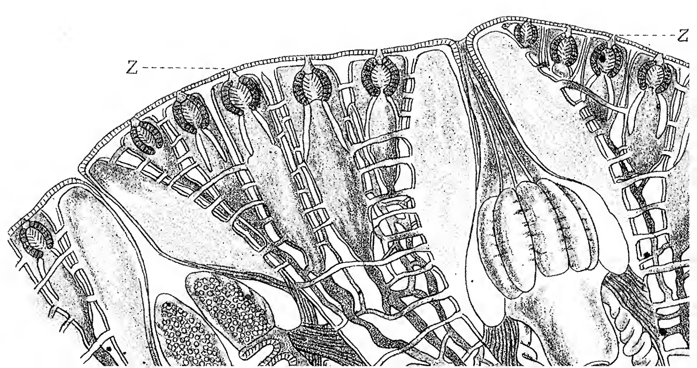
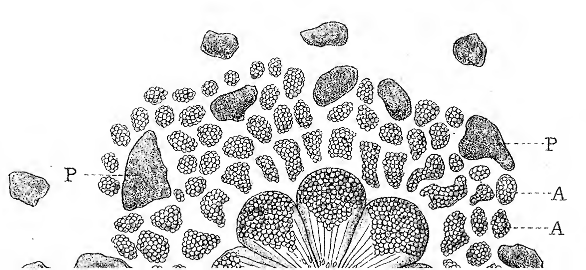
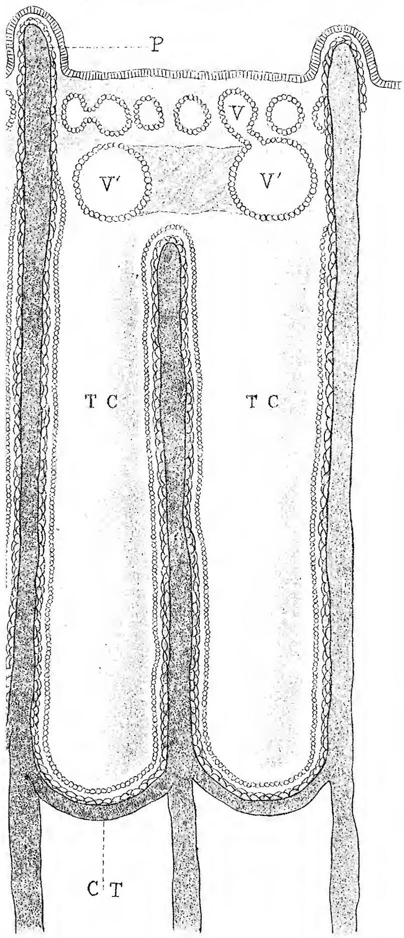




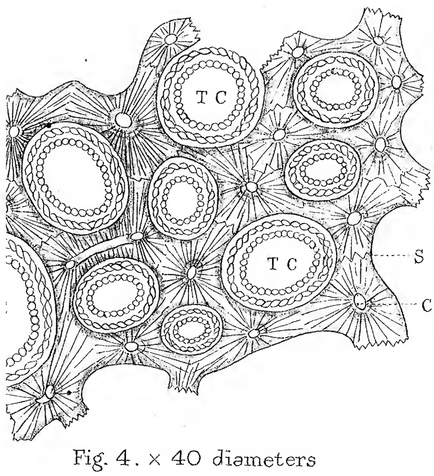
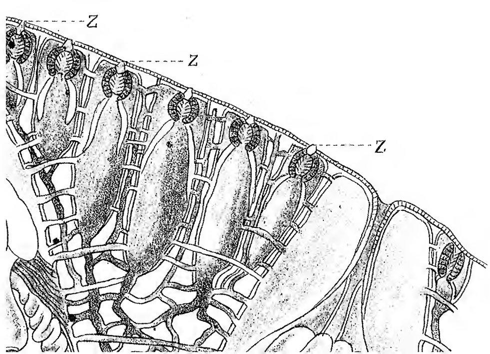




Fig. 4. × 40 diameters



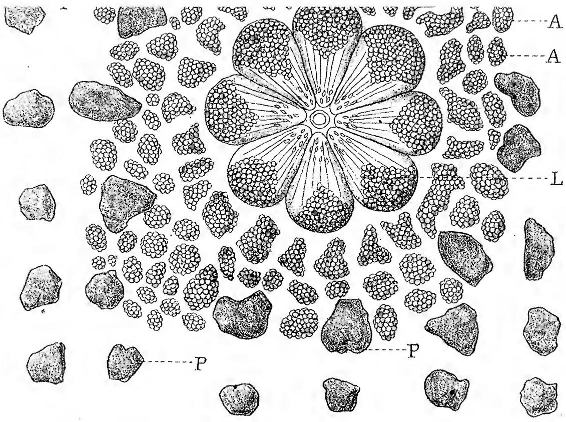


Fig. 5. × 25 diameters

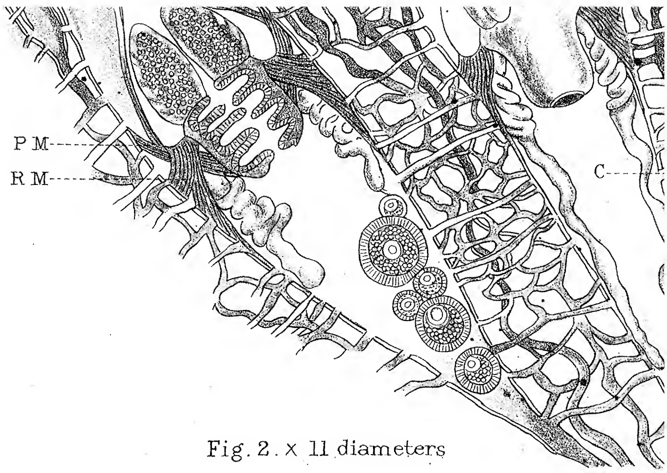
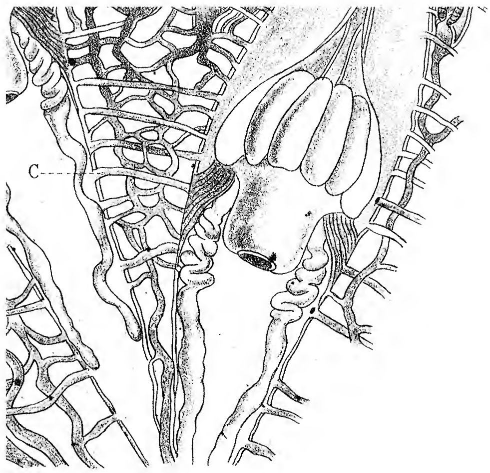


Fig. 2. × 11 diameters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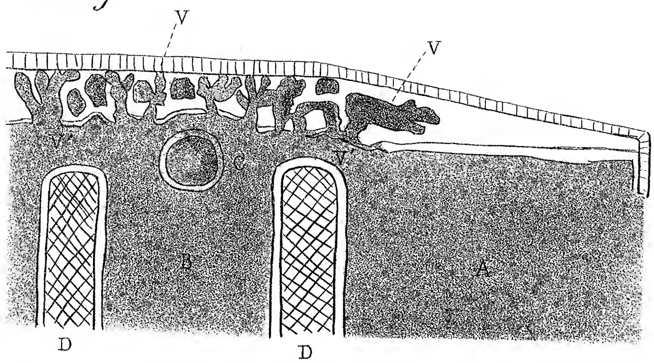


Fig. 7.

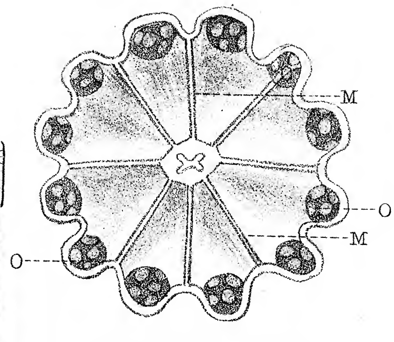


Fig. 8. × 20 diameters.

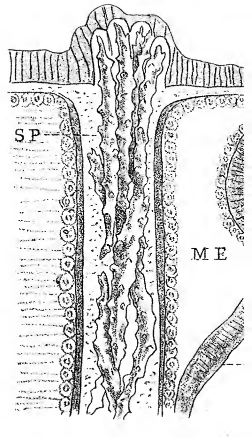


Fig.

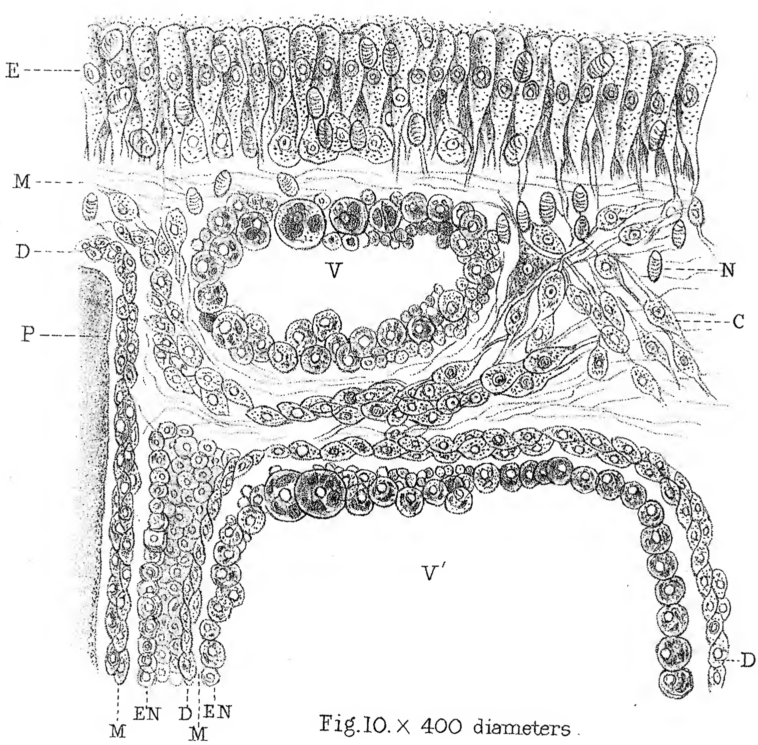


Fig. 10. × 400 diameters.

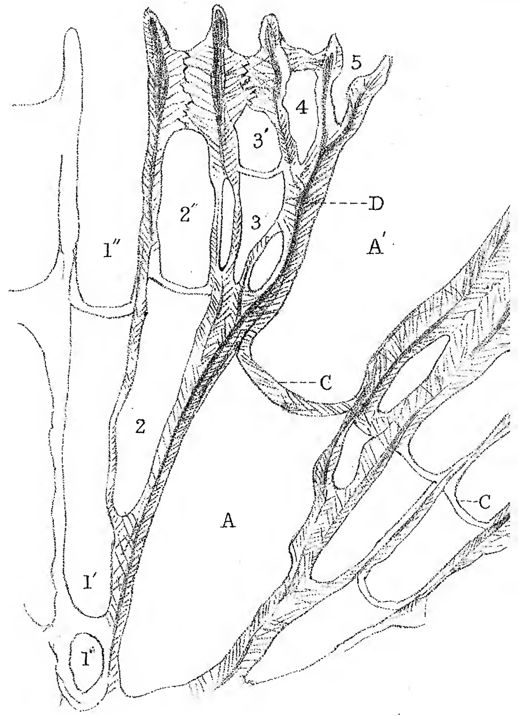


Fig 11. × 15

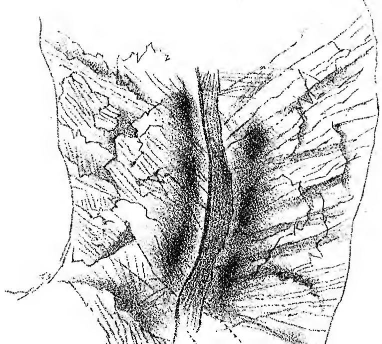
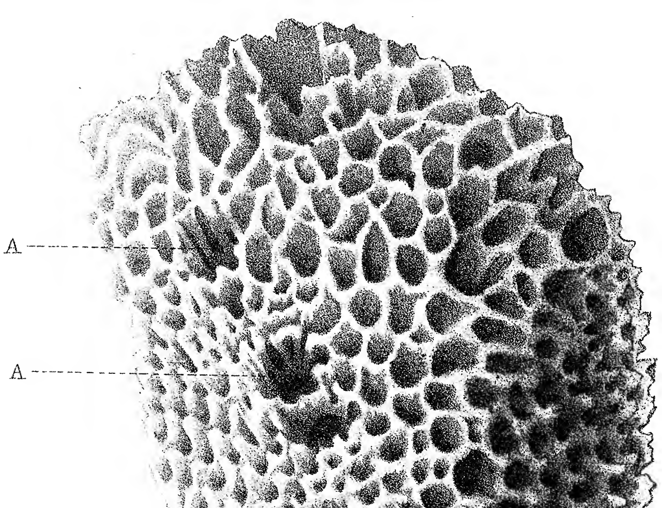
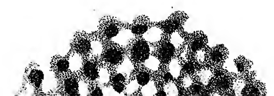


Fig. 12. × 250 diameters



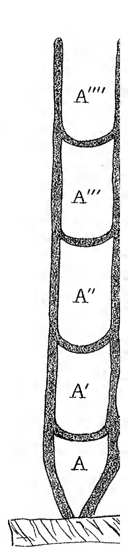


Fig. 15

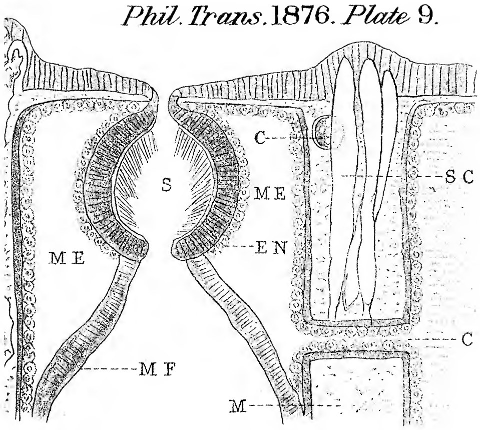
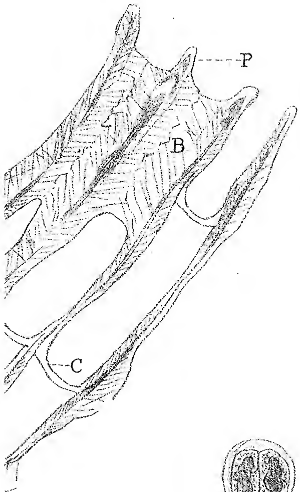



Fig. 9. × 60 diameters



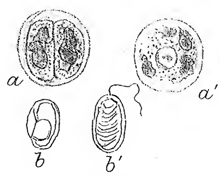




Fig. 13.
*a* × 670, *b* × 830 diars

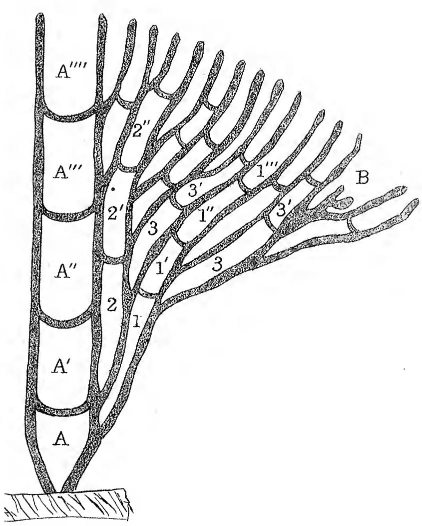



Fig. 15.

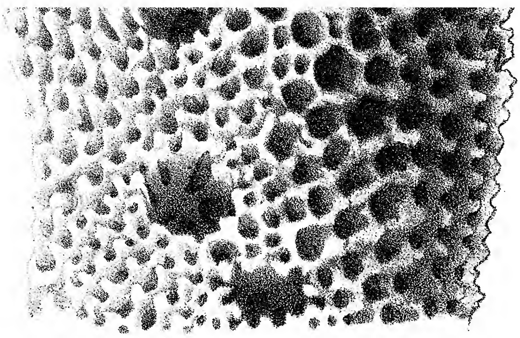


Fig. 16. × 8.

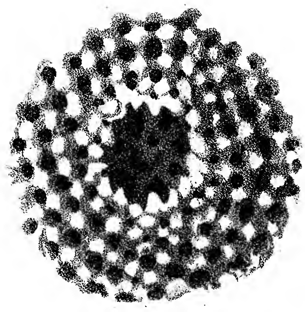


Fig. 17. × 10

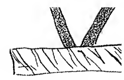


Fig. 15.

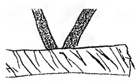


Fig. 15.

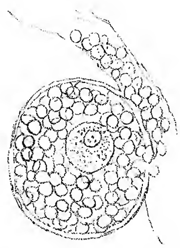


Fig. 14. × 80 diameters

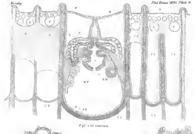


Fig. 1. × 42 diameters

Fig. 3. × 50 diameters

Fig. 6. × 20 diameters

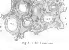


Fig. 4. × 40 diameters

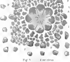


Fig. 5. 4 diameters

Fig. 2. × 11 diameters

Fig 7

Fig 8

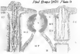


Fig 9 × 60 diameters

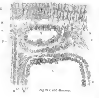


Fig 10 × 400 diameters

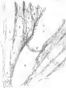


Fig 11 × 15

Fig 13

Fig 14 × 4

Fig 12 × 50

Fig 17 × 10

Fig 15

Fig 16 × 60 diameters